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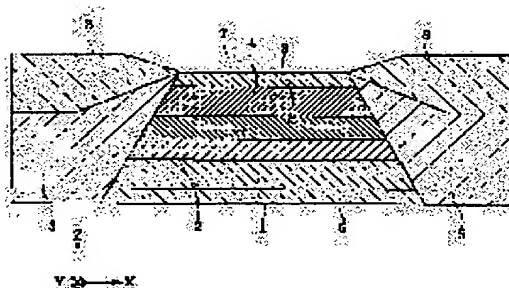
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(54) EXCHANGE COUPLING FILM, MAGNETORESISTANCE EFFECT ELEMENT USING THIS EXCHANGE COUPLING FILM AND THIN-FILM MAGNETIC HEAD USING THE MAGNETORESISTANCE EFFECT ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide an exchange coupling film, formed such that when an antiferromagnetic material containing an element (X) ((X) is a platinum group element.) and an element Mn is used as an antiferromagnetic layer, a large exchange anisotropic magnetic field can be generated, and a magnetoresistance effect element using the exchange coupling film.

SOLUTION: An exchange coupling film is formed such that an antiferromagnetic layer 4 is formed of an X-Mn ((X) is a platinum group element.) layer and the compositional ratio of the (X) is regulated properly, whereby the interfacial structure between the layer 4 and a fixed magnetic layer 3 is put in a non-aligned form, and in the state, the layer 4 is subjected to heat treatment, whereby the crystal structure of the layer 4 is transformed so that a large exchange anisotropic magnetic field can be obtained. Thereby, it is possible to further improve the regenerating characteristics of the exchange coupling film in comparison with those of the conventional methods.



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CLAIMS

[Claim(s)]

- [Claim 1] By an antiferromagnetism layer and a ferromagnetic layer touching, forming them and performing heat treatment in the switched connection film with which an exchange anisotropy field occurs in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is fixed in the fixed direction said antiferromagnetism layer. Switched connection film characterized by being formed with the antiferromagnetism ingredient which contains Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn at least, and the interface structure of said antiferromagnetism layer and ferromagnetic layer being in a disconformity condition.
- [Claim 2] Switched connection film according to claim 1 with which a part of [at least] crystal structures of said antiferromagnetism layer after heat treatment serve as a face-centered square superlattice of L10 mold.
- [Claim 3] Switched connection film according to claim 1 or 2 with which the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer differs in the interface of said antiferromagnetism layer and ferromagnetic layer.
- [Claim 4] The amount of preferred orientation of the {111} sides of said antiferromagnetism layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said ferromagnetic layer, or serves as non-orientation to the {111} sides of said ferromagnetic layer carrying out priority orientation in the direction parallel to an interface with said antiferromagnetism layer.
- [Claim 5] The amount of preferred orientation of the {111} sides of said ferromagnetic layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said antiferromagnetism layer, or serves as non-orientation to the {111} sides of said antiferromagnetism layer carrying out priority orientation in the direction parallel to an interface with said ferromagnetic layer.
- [Claim 6] Both the amount of preferred orientation of the {111} sides of said antiferromagnetism layer to a direction parallel to the interface of said antiferromagnetism layer and ferromagnetic layer and the amount of preferred orientation of the {111} sides of said ferromagnetic layer are switched connection film according to claim 3 with which it is small, or has become non-orientation, priority orientation of the crystal faces other than the aforementioned {111} sides is carried out in the direction parallel to an interface, and the crystal orientation of an antiferromagnetism layer and a ferromagnetic layer differs.
- [Claim 7] It is the switched connection film according to claim 1 to 6 whose element X said antiferromagnetism layer is formed with a X-Mn alloy, and is Pt.
- [Claim 8] the ratio of the lattice constants a and c of said antiferromagnetism [said antiferromagnetism layer is formed with a PtMn alloy, and] layer after heat treatment — the switched connection film according to claim 7 whose c/a is within the limits of 0.93-0.99.
- [Claim 9] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). It is formed, the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — said X-Mn-X' alloy. Switched connection film according to claim 1 to 6 a part of whose lattice point of the crystal lattice which consists of elements X and Mn it is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or is the substitution solid solution permuted by element X'.
- [Claim 10] The element X of the X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 which is Pt.
- [Claim 11] Said element X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and switched connection film according to claim 9 or 10 which is one sort or two sorts or more of elements among rare earth elements.
- [Claim 12] Said element X' is switched connection film according to claim 11 which is one sort or two sorts or more of elements among Ne, Ar, Kr, and Xe.
- [Claim 13] The presentation ratio of said element X' is switched connection film according to claim 9 to 12 which is at% and is within the limits of 0.2-10.
- [Claim 14] The presentation ratio of said element X' is switched connection film according to claim 13 which is at% and is within the limits of 0.5-5.
- [Claim 15] X:Mn is switched connection film of a presentation ratio with Elements X and Mn according to claim 13 or 14 which is within the limits of 4:6-6:4 comparatively.
- [Claim 16] The X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 to 15 formed of a spatter.
- [Claim 17] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 47-57.
- [Claim 18] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 47-57.

[Claim 19] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 17 or 18 which is at% and is within the limits of 50-56.

[Claim 20] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 44-57.

[Claim 21] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements - one sort or two sorts or more of elements - it is - the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 44-57.

[Claim 22] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 20 or 21 which is at% and is within the limits of 46-55.

[Claim 23] An antiferromagnetism layer and the fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange anisotropy field with said antiferromagnetism layer, The free magnetic layer formed in said fixed magnetic layer through the nonmagnetic conductive layer, The bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction, It has a fixed magnetic layer, a nonmagnetic conductive layer, and the conductive layer that gives a detection current to a free magnetic layer. The magneto-resistive effect component characterized by forming the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 24] The magneto-resistive effect component according to claim 23 currently formed with the switched connection film with which spacing of the width of recording track Tw was vacated for said free magnetic layer top or bottom, the laminating of the antiferromagnetism layer was carried out, and said antiferromagnetism layer and free magnetic layer were indicated by either claim 1 thru/or claim 22.

[Claim 25] The nonmagnetic conductive layer to which the laminating of the free magnetic layer was carried out up and down, and the fixed magnetic layer located on said one nonmagnetic conductive layer and under the nonmagnetic conductive layer of another side, It is located on said one fixed magnetic layer and under the fixed magnetic layer of another side. The antiferromagnetism layer which fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange anisotropy field, It has the bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction. The magneto-resistive effect component characterized by forming the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 26] The magneto-resistive effect component characterized by having the magnetic-reluctance layer and soft magnetism layer which were piled up through the non-magnetic layer, vacating spacing of the width of recording track Tw for said magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming said antiferromagnetism layer and magnetic-reluctance layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 27] The thin film magnetic head characterized by the thing of the magneto-resistive effect component indicated by claim 23 thru/or either of 26 for which the shielding layer is formed through the gap layer up and down.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] By the exchange anisotropy field which this invention consists of an antiferromagnetism layer and a ferromagnetic layer, and is generated in the interface of said antiferromagnetism layer and ferromagnetic layer The switched connection film with which the magnetization direction of said ferromagnetic layer is fixed in the fixed direction is started. When said especially antiferromagnetism layer is formed with the antiferromagnetism ingredient containing Elements X (Pt, Pd, etc.) and Mn, it is related with the switched connection film which enabled it to acquire a larger exchange anisotropy field, and the magneto-resistive effect component (a spin bulb mold thin film, AMR component) using this switched connection film.

[0002]

[Description of the Prior Art] A spin bulb mold thin film is one sort using giant magneto-resistance of a GMR (giant magnetoresistive) component, and detects the record field from record media, such as a hard disk. This spin bulb mold thin film has the point which was excellent in some — also in a GMR component, structure is comparatively simple and, moreover, resistance changes by the weak field.

[0003] Said spin bulb mold thin film is the simplest structure, and consists of an antiferromagnetism layer, a fixed magnetic layer, a nonmagnetic conductive layer, and a free magnetic layer. the exchange anisotropy field which said antiferromagnetism layer and fixed magnetic layer touch, and it is formed, and is generated in the interface of said antiferromagnetism layer and fixed magnetic layer — the magnetization direction of said fixed magnetic layer — the fixed direction — a single domain — it is-izing and fixed. Magnetization of a free magnetic layer is arranged in the magnetization direction of said fixed magnetic layer, and the crossing direction by the bias layer formed in the both sides.

[0004] Generally the Co-Pt (cobalt-platinum) alloy film etc. is used for Cu (copper) film and a bias layer by the Fe-Mn (iron-manganese) alloy film or the nickel-Mn (nickel-manganese) alloy film, the fixed magnetic layer, and the free magnetic layer at the nickel-Fe (nickel-iron) alloy film and the nonmagnetic conductive layer 3 at said antiferromagnetism layer.

[0005] In this spin bulb mold thin film, if the magnetization direction of said free magnetic layer is changed, electric resistance will change with the leakage fields from record media, such as a hard disk, by relation with the fixed magnetization direction of a fixed magnetic layer, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.

[0006] By the way, although the Fe-Mn alloy film and the nickel-Mn alloy film are used for an antiferromagnetism layer as mentioned above, the Fe-Mn alloy film has low corrosion resistance, and an exchange anisotropy field is small and blocking temperature is low with about 150 degrees C further. The problem that an exchange anisotropy field will disappear occurs by the rise of the chip temperature under the production process of a head, and head actuation because blocking temperature is low. On the other hand, compared with the Fe-Mn alloy film, the nickel-Mn alloy film has a comparatively large exchange anisotropy field, and, moreover, its blocking temperature is as high as about 300 degrees C. Therefore, it is more desirable to use the nickel-Mn alloy film for an antiferromagnetism layer rather than the Fe-Mn alloy film.

[0007] Moreover, B.Y.Wong, C.Mitsumata, S.Prakash, D.E.Laughlin, and T.Kobayashi:Journal of Applied The interface structure of said antiferromagnetism layer and fixed magnetic layer (NiFe alloy film) at the time of using the nickel-Mn alloy film as an antiferromagnetism layer is reported to Physics, vol.79, No10, and p.7896-p.7904 (1996).

[0008] This paper "the crystal adjustment condition in a NiFe/NiMn interface is maintained, and it is growing up so that the {111} sides of both NiFe and NiMn may become parallel to a film surface. The adjustment distortion by the interface is eased by introducing much twin crystal which makes a field parallel to a film surface a twin plane. However, regulation-ization of NiMn near the interface is low controlled by extant interface distortion, and whenever [regulation-ized] is high by it in the location distant from the interface. It is indicated as ".

[0009] In addition, the thing in the condition that the atom of an antiferromagnetism layer and a fixed magnetic layer corresponds by 1 to 1 is said, and disconformity says conversely the thing in the condition that there is no atom of the antiferromagnetism layer and fixed magnetic layer in an interface in the physical relationship of a pair. [in / in adjustment / an interface]

[0010] Although an exchange anisotropy field occurs in the interface of a NiMn alloy and a fixed magnetic layer by performing heat treatment when an antiferromagnetism layer is formed with a NiMn alloy, a NiMn alloy depends this on metamorphosing into a superlattice from an irregular grid by performing heat treatment.

[0011] If heat treatment is performed although the crystal structure of a NiMn alloy is a face-centered cubic lattice (henceforth an irregular grid) with the irregular array sequence of nickel and Mn atom before heat treatment is performed, the crystal structure will metamorphose into a face centred tetragonal lattice from a face-centered cubic lattice, and, moreover, an atomic location will regulation-ize it (henceforth a superlattice). in addition, the ratio of the lattice constants a and c of the nickel-Mn alloy film when the crystal structure becomes a superlattice completely — c/a is 0.942.

[0012] Thus, since lattice constant ratio c/a of the NiMn alloy film which became a superlattice completely is a value comparatively near 1, even if it is comparatively small, therefore the interface structure of the NiMn alloy film and a fixed magnetic layer is in an adjustment condition, by performing heat treatment, a NiMn alloy metamorphoses into a superlattice from an irregular grid, and an exchange anisotropy field generates the grid distortion by the interface produced when metamorphosing into a superlattice from an irregular grid. In addition, the grid distortion in an interface is eased to some extent with twin crystal as indicated by the paper mentioned above.

[0013] [Problem(s) to be Solved by the Invention] As mentioned above, although as for the NiMn alloy the exchange anisotropy

field has become , and blocking temperature has also become as high as about 300 degrees C and it had the property which was excellent compared with the conventional FeMn alloy, it was not able to say comparatively that it was enough like the FeMn alloy about corrosion resistance.

[0014] So, recently, it excels in corrosion resistance, moreover a larger exchange anisotropy field than a NiMn alloy is generated, and the X-Mn alloy (X=Pt, Pd, Ir, Rh, Ru, Os) using platinum group metals as an antiferromagnetism ingredient which has high blocking temperature is capturing the spotlight. If the X-Mn alloy containing platinum group metals is used as an antiferromagnetism layer, a playback output can be raised compared with the former, and an exchange anisotropy field will be extinguished and it will be hard coming to also generate the fault that reproducing characteristics fall, by the rise of the chip temperature at the time of head drive actuation.

[0015] By the way, when the X-Mn alloy containing these platinum group metals is used as an antiferromagnetism layer, in order to generate an exchange anisotropy field, it is necessary to perform a membrane formation postheat treatment like the case where a NiMn alloy is used as an antiferromagnetism layer. According to the reference which was mentioned above in the case of the NiMn alloy, it was indicated that the interface structure with a fixed magnetic layer (NiFe alloy) was in an adjustment condition, but it turned out that an exchange anisotropy field hardly occurs even if it will heat-treat also in a X-Mn alloy (X is platinum group metals), if interface structure with a fixed magnetic layer is similarly made into the adjustment condition.

[0016] This invention is for solving the above-mentioned conventional technical problem, and when the antiferromagnetism ingredient containing Elements X (X is platinum group metals) and Mn is used as an antiferromagnetism layer, it relates to the switched connection film which enabled it to generate a large exchange anisotropy field, and the magneto-resistive effect component using this switched connection film.

[0017]

[Means for Solving the Problem] This invention by an antiferromagnetism layer and a ferromagnetic layer touching, forming them and performing heat treatment in the switched connection film with which an exchange anisotropy field occurs in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is fixed in the fixed direction said antiferromagnetism layer. It is formed with the antiferromagnetism ingredient which contains Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn at least, and interface structure of said antiferromagnetism layer and ferromagnetic layer is characterized by being in a disconformity condition.

[0018] Moreover, it is desirable that a part of [at least] crystal structures of said antiferromagnetism layer after heat treatment serve as a face-centered square superlattice of L10 mold. It is desirable that the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer furthermore differs according to the interface of said antiferromagnetism layer and ferromagnetic layer by this invention.

[0019] In this invention, to the {111} sides of said ferromagnetic layer carrying out priority orientation in the direction parallel to an interface with said antiferromagnetism layer, the amount of preferred orientation of the {111} sides of said antiferromagnetism layer is smaller than the amount of preferred orientation of said ferromagnetic layer, or serves as non-orientation.

[0020] Or to the {111} sides of said antiferromagnetism layer carrying out priority orientation in the direction parallel to an interface with said ferromagnetic layer, the amount of preferred orientation of the {111} sides of said ferromagnetic layer is smaller than the amount of preferred orientation of said antiferromagnetism layer, or serves as non-orientation.

[0021] Or both the amount of preferred orientation of the {111} sides of said antiferromagnetism layer to a direction parallel to the interface of said antiferromagnetism layer and ferromagnetic layer and the amount of preferred orientation of the {111} sides of said ferromagnetic layer are small, or serve as non-orientation, priority orientation of the crystal faces other than the aforementioned {111} sides is carried out in the direction parallel to an interface, and the crystal orientation of an antiferromagnetism layer and a ferromagnetic layer differs.

[0022] Moreover, in this invention, said antiferromagnetism layer is formed with a X-Mn alloy, and, as for Element X, it is desirable that it is Pt. furthermore, the ratio of the lattice constants a and c of said antiferromagnetism layer after heat treatment when said antiferromagnetism layer is formed with a PtMn alloy — as for c/a, it is desirable that it is within the limits of 0.93-0.99.

[0023] Or at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X). It is formed, the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — said X-Mn-X' alloy. It is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or a part of lattice point of the crystal lattice which consists of elements X and Mn is the substitution solid solution permuted by element X'. Especially the element X of the X-Mn-X' alloy used as said antiferromagnetism layer is Pt, i.e., being formed with the Pt-Mn-X' alloy is [said antiferromagnetism layer] desirable.

[0024] In this invention, in addition, element X' of the X-Mn-X' alloy used as said antiferromagnetism layer Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, And it is desirable that they are one sort or two sorts or more of elements among rare earth elements, and said element X' is one sort or two sorts or more of elements among Ne, Ar, Kr, and Xe more preferably.

[0025] Moreover, in this invention, when said antiferromagnetism layer is formed with a X-Mn-X' alloy, it is desirable that the presentation ratio of X' is at% and it is within the limits of 0.2-10, and it is within the limits of 0.5-5 more preferably.

[0026] When said antiferromagnetism layer is furthermore formed with a X-Mn-X' alloy by this invention, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. In addition, as for the X-Mn-X' alloy used as said antiferromagnetism layer, being formed of a spatter is desirable.

[0027] In this invention, said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed on the ferromagnetic layer, it is at% and, as for the presentation ratio of X of a X-Mn alloy, it is desirable that it is within the limits of 47-57.

[0028] Moreover, at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed and said antiferromagnetism layer is formed on the ferromagnetic layer, it is at% and, as for the presentation ratio of X+X' of a X-Mn-X' alloy, it is desirable that it is within the limits of 47-57.

[0029] It is more more desirable still that the presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is within the limits of 50-56 in this invention.

[0030] In this invention, said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, it is at% and, as for the presentation ratio of X of a X-Mn alloy, it is desirable that it is within the limits of 44-57.

[0031] Moreover, at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed and said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, it is at% and, as for the presentation ratio of X+X' of a X-Mn-X' alloy, it is desirable that it is within the limits of 44-57.

[0032] It is more more desirable still that the presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is within the limits of 46-55 in this invention.

[0033] The switched connection film formed as mentioned above is usable for various magneto-resistive effect components in this invention. First the single spin bulb mold thin film in this invention An antiferromagnetism layer and the fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange anisotropy field with said antiferromagnetism layer. The free magnetic layer formed in said fixed magnetic layer through the nonmagnetic conductive layer. The bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction. It has a fixed magnetic layer, a nonmagnetic conductive layer, and the conductive layer that gives a detection current to a free magnetic layer, and the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the switched connection film mentioned above.

[0034] Moreover, in this invention, spacing of the width of recording track Tw may be vacated for the above-mentioned single spin bulb mold thin-film the top or the bottom of a free magnetic layer, an antiferromagnetism layer may be formed, and said antiferromagnetism layer and free magnetic layer may be formed with the switched connection film mentioned above.

[0035] Moreover, the dual spin bulb mold thin film in this invention The nonmagnetic conductive layer to which the laminating of the free magnetic layer was carried out up and down, and the fixed magnetic layer located on said one nonmagnetic conductive layer and under the nonmagnetic conductive layer of another side. It is located on said one fixed magnetic layer and under the fixed magnetic layer of another side. The antiferromagnetism layer which fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange anisotropy field. It has the bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction, and the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the switched connection film mentioned above.

[0036] Furthermore, the AMR component in this invention is characterized by having the magnetic-reluctance layer and soft magnetism layer which were piled up through the non-magnetic layer, vacating spacing of the width of recording track Tw for said magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming said antiferromagnetism layer and magnetic-reluctance layer with the switched connection film mentioned above. Moreover, the thin film magnetic head in this invention is characterized by the thing of the magneto-resistive effect component mentioned above for which the shielding layer is formed through the gap layer up and down.

[0037] When the antiferromagnetism ingredient which contains Elements X (any one sort or two sorts or more of elements among [X =] Pt, Pd, Ir, Rh, Ru, and Os) and Mn at least is used as an antiferromagnetism layer, it enables it to acquire an exchange anisotropy field to fitness by making interface structure with a ferromagnetic layer into a disconformity condition in this invention.

[0038] The reason for making interface structure with a ferromagnetic layer into a disconformity condition is for making the crystal structure of an antiferromagnetism layer metamorphose into a superlattice from an irregular grid at fitness, and generating a larger exchange anisotropy field, when heat-treating. Below, the relation of said disconformity condition and exchange anisotropy field is explained in full detail.

[0039] First, although a disconformity condition means that the atom by the side of said antiferromagnetism layer and the atom by the side of a ferromagnetic layer do not correspond to 1 to 1, but atomic physical relationship differs in the interface of an antiferromagnetism layer and a ferromagnetic layer, in order to make interface structure into a disconformity condition in this way, it is necessary to control the lattice constant of the antiferromagnetism layer before heat treatment to fitness.

[0040] In this invention, said antiferromagnetism layer is formed for example, with a X-Mn alloy (any one sort or two sorts or more of elements among [However, X] Pt, Pd, Ir, Rh, Ru, and Os).

[0041] He chooses the presentation ratio of X of said X-Mn alloy as fitness, and is trying for the difference of the value of the lattice constant of the X-Mn alloy before heat treatment and the value of the lattice constant of a ferromagnetic layer (for example, NiFe alloy) to become large in this invention.

[0042] Although the array sequence of X and Mn atom both serves as an irregular face-centered cubic lattice (henceforth an irregular grid), the crystal structure of a X-Mn alloy and the crystal structure of a ferromagnetic layer in a membrane formation phase (before heat treatment) Since the difference of the lattice constant of a X-Mn alloy and the lattice constant of a ferromagnetic layer is enlarged as mentioned above in this invention, the interface structure of the X-Mn alloy in a membrane formation phase (before heat treatment) and a ferromagnetic layer will be easy to be in a disconformity condition.

[0043] Thus, although the interface condition of an antiferromagnetism layer and a ferromagnetic layer is changed into the disconformity condition by choosing the presentation ratio of Element X proper in this invention when a X-Mn alloy (X is Pt, Pd, etc.) is used as an antiferromagnetism layer Furthermore by this invention, it is possible to be able to enlarge the lattice constant of an antiferromagnetism layer and to change the interface structure of said antiferromagnetism layer and ferromagnetic layer into a disconformity condition by making a X-Mn alloy contain element X', such as rare-gas elements (Ne, Ar, etc.).

[0044] Moreover, it is desirable to make it the crystal orientation of a X-Mn alloy or an X-Mn-X' alloy, and a ferromagnetic layer differ in this invention. The crystal amount of preferred orientation can be changed by terms and conditions, such as existence or nonexistence of a substrate layer, and a presentation ratio, power gas pressure at the time of spatter membrane formation, or the membranous order of a laminating.

[0045] Thus, it is because interface structure will stop being able to grow into a disconformity condition easily if for example, the {111} sides of a ferromagnetic layer carry out priority orientation of making it the crystal orientation of a X-Mn alloy or a X-Mn-X' alloy, and a ferromagnetic layer differ in parallel with a film surface and the {111} sides of a X-Mn alloy or an X-Mn-X' alloy are carrying out priority orientation in parallel with a film surface similarly.

[0046] So, in this invention, when the {111} sides of a ferromagnetic layer are carrying out priority orientation in the direction parallel to an interface with an X-Mn alloy or a X-Mn-X' alloy, for example, the amount of preferred orientation of the {111} sides of a X-Mn alloy or a X-Mn-X' alloy is smaller than the amount of preferred orientation of said ferromagnetic layer, or it is controlling to fitness so that it may become non-orientation, and becomes possible [maintaining interface structure at a

disconformity condition].

[0047] As mentioned above, although an exchange anisotropy field occurs in the interface of a X-Mn alloy or a X-Mn-X' alloy, and a ferromagnetic layer by performing heat treatment after carrying out the laminating of a X-Mn alloy or a X-Mn-X' alloy, and the ferromagnetic layer so that interface structure may be in a disconformity condition. The crystal structure of a X-Mn alloy or an X-Mn-X' alloy depends generating of this exchange anisotropy field on metamorphosing into the face centred tetragonal lattice decided by the array sequence of X and Mn atom having regularity from said irregular phase.

[0048] In addition, in this invention, said face centred tetragonal lattice is the so-called L10 type of face centred tetragonal lattice (henceforth a superlattice) which X atom occupies the core of the 4th page of a side face among the 6th page of a unit lattice, and Mn atom occupies at the core of the corner of a unit lattice, a top face, and an inferior surface of tongue, and a part of [at least] crystal structures of the X-Mn alloy after heat treatment or a X-Mn-X' alloy need to serve as said superlattice.

[0049] As mentioned above, although the crystal structure of a X-Mn alloy or an X-Mn-X' alloy metamorphoses into a superlattice from an irregular grid and a switched connection field occurs by heat-treating, as for grid distortion produced in the case of this transformation, the direction of a X-Mn alloy or a X-Mn-X' alloy is large compared with the NiMn alloy.

[0050] In this invention, as mentioned above, the interface structure of the X-Mn alloy before heat treatment or an X-Mn-X' alloy, and a ferromagnetic layer changes into a disconformity condition fitness-izing the presentation ratio of a X-Mn alloy, or by adding element X' as the 3rd element into a X-Mn alloy.

[0051] If the interface structure of an antiferromagnetism layer and a ferromagnetic layer is changed into a disconformity condition, by heat-treating, the crystal structure of an X-Mn alloy or a X-Mn-X' alloy will become easy to metamorphose into a superlattice from an irregular grid, therefore a big exchange anisotropy field will generate it in said interface. In addition, X-Mn alloys (X=Pt, Pd, etc.) or X-Mn-X' alloys (X'=Ne, Ar, etc.) have the property which was excellent in corrosion resistance compared with the FeMn alloy, the NiMn alloy, etc., and was excellent compared with the FeMn alloy etc. as an antiferromagnetism ingredient — blocking temperature is also high and an exchange anisotropy field (Hex) is still larger.

Moreover, it is desirable to choose Pt as the element X which constitutes a X-Mn alloy or a X-Mn-X' alloy from this invention.

[0052] The switched connection film which consists of the antiferromagnetism layer formed with the X-Mn alloy explained in full detail above or the X-Mn-X' alloy and a ferromagnetic layer can be applied to a magneto-resistive effect component.

[0053] In this invention, the antiferromagnetism layer and fixed magnetic layer of a single spin bulb mold thin film and a dual spin bulb mold thin film are formed with said switched connection film, for example as said magneto-resistive effect component. It is possible to acquire the reproducing characteristics which became possible [fixing magnetization of said fixed magnetic layer in the fixed direction firmly] by this, and were excellent compared with the former.

[0054] Moreover, when arranging the magnetization direction of the free magnetic layer of for example, a single spin bulb mold thin film, or the magneto-resistive effect component layer of the AMR component in the fixed direction with an exchange bias method, an exchange bias layer, a free magnetic layer or an exchange bias layer, and a magnetic-reluctance layer may be formed with said switched connection film. It is possible for this to become possible to arrange magnetization of said free magnetic layer and a magnetic-reluctance layer with fitness in the fixed direction, and to acquire outstanding reproducing characteristics.

[0055]

[Embodiment of the Invention] Drawing 1 is the sectional view which looked at the structure of the single spin bulb mold thin film of the 1st operation gestalt of this invention from the ABS side side. In addition, drawing 1 fractures and shows only the central part of the component prolonged in the direction of X. This single spin bulb mold thin film is prepared in the trailing side edge section of the surfacing type slider formed in the hard disk drive unit etc., and detects record fields, such as a hard disk. In addition, the migration direction of magnetic-recording media, such as a hard disk, is a Z direction, and the direction of the leak field from a magnetic-recording medium is the direction of Y.

[0056] The substrate layer 6 formed by non-magnetic materials, such as Ta (tantalum), is formed in the bottom of drawing 1. The laminating of the free magnetic layer 1, the nonmagnetic conductive layer 2, the fixed magnetic layer 3, and the antiferromagnetism layer 4 is carried out on this substrate layer 6. And the protective layers 7, such as Ta (tantalum), are formed on said antiferromagnetism layer 4.

[0057] Moreover, as shown in drawing 1, the hard bias layers 5 and 5 are formed in the both sides of six layers from the substrate layer 6 to a protective layer 7, and the laminating of the conductive layers 8 and 8 is carried out on said hard bias layers 5 and 5.

[0058] In this invention, said free magnetic layer 1 and the fixed magnetic layer 3 are formed with a NiFe alloy, a CoFe alloy, Co alloy, Co, a CoNiFe alloy, etc. in addition, although the free magnetic layer 1 comes out further and it is formed as shown in drawing 1, this may be formed by multilayer structure. That is, the structure where said free magnetic layer 1 may have the structure where the laminating of for example, a NiFe alloy and the CoFe alloy was carried out, and the laminating of a NiFe alloy and the Co was carried out is sufficient.

[0059] The nonmagnetic conductive layer 2 which intervenes between said free magnetic layers 1 and fixed magnetic layers 3 is formed by Cu. Furthermore, the hard bias layers 5 and 5 are formed with for example, the Co-Pt (cobalt-platinum) alloy, the Co-Cr-Pt (cobalt chrome-platinum) alloy, etc., and conductive layers 8 and 8 are formed by Cu (copper), W (tungsten), Cr (chromium), etc.

[0060] In this invention, the antiferromagnetism layer 4 currently formed on the fixed magnetic layer 3 is formed at least with the antiferromagnetism ingredient containing Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn.

[0061] In this invention, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 which are shown in drawing 1 is in the disconformity condition, and a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface serve as a face centred tetragonal lattice (henceforth a superlattice) of L10 mold.

[0062] Here, the face centred tetragonal lattice of L10 mold means what X atom (X=Pt, Pd, Ir, Rh, Ru, Os) occupies the core of the 4th page of a side face among the 6th page of a unit lattice, and Mn atom occupies at the core of the corner of a unit lattice, a top face, and an inferior surface of tongue.

[0063] Moreover, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is desirable at the point that it will tend to be in a disconformity condition in this invention that the crystal orientation of the fixed magnetic layer 3 and the antiferromagnetism layer 4 differs.

[0064] drawing 1 — being shown — a single — a bulb — a mold — a thin film — **** — Ta — a substrate — a layer — six — covering — **** — since — said — a substrate — a layer — six — a top — forming — having — free — a magnetic layer — one — nonmagnetic — a conductive layer — two — and — immobilization — a magnetic layer — three — (— 111 —) — a field

— a film surface — receiving — being parallel — a direction — priority — orientation — carrying out — ****.

[0065] On the other hand, the {111} sides of the antiferromagnetism layer 4 formed on said fixed magnetic layer 3 are small compared with the amount of preferred orientation of the {111} sides of said fixed magnetic layer 3, or serve as non-orientation. That is, the crystal orientation near the interface of the fixed magnetic layer 3 and the antiferromagnetism layer 4 which are shown in drawing 1 is a different thing, therefore the structure in said interface will be easy to be in a disconformity condition.

[0066] Although interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is made into the disconformity condition from the phase before heat treatment in this invention, this is because it is made to metamorphose into the superlattice which mentioned above the crystal structure of said antiferromagnetism layer 4 from the irregular grid (face-centered cubic lattice) and a fitness exchange anisotropy field can be acquired by heat-treating. If it says and changes and interface structure is in an adjustment condition, even if it heat-treats, the crystal structure of said antiferromagnetism layer 4 cannot metamorphose into a superlattice easily from an irregular grid, therefore the problem that an exchange anisotropy field is not acquired will arise.

[0067] In this invention, said antiferromagnetism layer 4 is formed with the X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os). It is desirable that said antiferromagnetism layer 4 is especially formed with the PtMn alloy by this invention. The X-Mn alloy, especially the PtMn alloy have the property which is excellent in thermal resistance compared with a FeMn alloy, a NiMn alloy, etc. which are used as an antiferromagnetism layer from the former, and was excellent as an antiferromagnetism ingredient — blocking temperature is also high and an exchange anisotropy field (Hex) is still larger.

[0068] the ratio of the lattice constants a and c of said antiferromagnetism layer 4 from which a part of [at least] crystal structures became a superlattice when said antiferromagnetism layer 4 is formed with the PtMn alloy after heat-treating in this invention that is, — as for c/a , it is desirable that it is within the limits of 0.93–0.99. the ratio of lattice constants a and c — if c/a becomes 0.93 or less — the crystal structure of said antiferromagnetism layer 4 — although all serve as a superlattice mostly, if it will be in such a condition, the adhesion of said fixed magnetic layer 3 and antiferromagnetism layer 4 falls, and film peeling etc. generates and is not desirable. the ratio of lattice constants a and c — it becomes [the exchange anisotropy field of the crystal structure of said antiferromagnetism layer 4 generated in the interface of said antiferromagnetism layer 4 and fixed magnetic layer 3 by all becoming an irregular grid mostly] small and is not desirable if c/a becomes 0.99 or more.

[0069] By the way, said antiferromagnetism layer 4 is a X-Mn alloy (however, X). the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — in the phase before heat treatment, in order to make interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 into a disconformity condition when formed In this invention, the presentation ratio of said X-Mn alloy is set up in the following numeric value.

[0070] As moreover shown in drawing 1, when said antiferromagnetism layer 4 is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os) and said antiferromagnetism layer 4 is formed on the fixed magnetic layer 3, the presentation ratio of the element X of a X-Mn alloy is at%, and it is desirable that it is within the limits of 47–57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50–56.

[0071] If the antiferromagnetism layer 4 is formed in presentation Hinai mentioned above, the difference of the lattice constant of said antiferromagnetism layer 4 of a before [heat treatment (i.e., the phase where the crystal structure serves as an irregular grid)], and the lattice constant of the fixed magnetic layer 3 can be enlarged, therefore the interface structure of said fixed magnetic layer 3 and antiferromagnetism layer 4 can be maintained at a disconformity condition before heat treatment.

[0072] If it heat-treats in this condition, as the exchange anisotropy field occurred and mentioned above by change of the crystal structure of said antiferromagnetism layer 4, the presentation ratio of the presentation ratio of the element X of an X-Mn alloy is at%, and it is possible to acquire the exchange anisotropy field more than 400 (Oe: oersted) as it is within the limits of 47–57. Moreover, the presentation ratio of the element X of a X-Mn alloy is at%, and it is possible to acquire the exchange anisotropy field more than 600 (Oe) as it is within the limits of 50–56.

[0073] Thus, when a X-Mn alloy is used as an antiferromagnetism layer 4 in this invention, it is possible to maintain the interface structure of said antiferromagnetism layer 4 and fixed magnetic layer 3 before heat treatment at a disconformity condition by forming within limits which mentioned the presentation ratio of Element X above. Moreover, it is possible by adding element X' as the 3rd element into a X-Mn alloy in this invention to be able to enlarge the lattice constant of the antiferromagnetism layer 4 and to change the interface structure of the antiferromagnetism layer 4 and the fixed magnetic layer 3 before heat treatment into a disconformity condition.

[0074] The X-Mn-X' alloy which added element X' to the X-Mn alloy is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or a part of lattice point of the crystal lattice which consists of elements X and Mn is the substitution solid solution permuted by element X'. The solid solution was crossed to the large presentation range, and has pointed out the thing of the solid-state with which the component was mixed with homogeneity here. In addition, as for Element X, in this invention, it is desirable that it is Pt.

[0075] By the way, in this invention, said X-Mn-X' alloy is formed by the spatter. Said X-Mn-X' alloy is formed by non-equilibrium by the spatter, and a part of lattice point of the crystal lattice which the formed X-Mn-X' alloy trespasses upon the clearance between space lattices where element X' in the film consists of elements X and Mn, or consists of elements X and Mn is permuted by element X' by it. thus, said element X' is an invasion mold at the grid of a X-Mn alloy — it is — by dissolving with a permutation mold, a grid can be extended and the lattice constant of the antiferromagnetism layer 4 becomes large compared with the case where element X' is not added.

[0076] Moreover, although it is possible to use various elements as element X' in this invention, if a reactant high halogen, O (oxygen), etc. are used, these carry out a chemical bond only to Mn alternatively, are considered with it becoming impossible to maintain the crystal structure of a face-centered cubic, and are not desirable. Concrete element X' in this invention Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb. And they are one sort or two sorts or more of elements among rare earth elements (Sc, Y, and lanthanoids (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)).

[0077] If the presentation ratio of said element X' becomes large too much when using element X' which dissolves especially with a permutation mold although the lattice constant of the antiferromagnetism layer 4 can be enlarged by the spatter even if it uses any of various element X' which showed above, the property as antiferromagnetism will fall and the switched connection field generated in an interface with the fixed magnetic layer 3 will become small.

[0078] By this invention, it especially dissolves with an invasion mold, and it is supposed that it is desirable to use the rare-gas element (one sort or two sorts or more among Ne, Ar, Kr, and Xe) of inert gas as element X'. It is gas by which it is not greatly

affected in an antiferromagnetism property even if a rare-gas element contains in the film, since a rare-gas element is inert gas, and Ar etc. is further introduced in the sputtering system from the former as sputtering gas, and is only adjusting gas pressure and spatter particle energy proper, and Ar can be made to invade into the film easily.

[0079] In addition, although it is difficult to contain a lot of element X' in the film when the element of a gas system is used for element X', in the case of rare gas, minute amount invasion is only carried out into the film, and it is checked by experiment that the switched connection field generated by heat treatment can be enlarged by leaps and bounds.

[0080] In addition, in this invention, the range of the presentation ratio of element X' is set up, and the desirable presentation range of said element X' is 0.2 to 10 at at%, is at% more preferably, and is 0.5 to 5. Moreover, as for X:Mn, it is comparatively desirable at this time that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. It is possible to enlarge the switched connection field generated in the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3 by being able to enlarge the lattice constant of the antiferromagnetism layer 4 in a membrane formation phase (before heat treatment) if it is within the limits and X:Mn is adjusted [above-mentioned] comparatively of the presentation ratio of element X' and a presentation ratio with Elements X and Mn, and moreover heat-treating compared with the case where element X' is not contained.

[0081] Furthermore at this invention, it is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, As shown in drawing 1 , when the formed antiferromagnetism layer 4 is formed on the fixed magnetic layer 3, the presentation ratio of X+X' of said X-Mn-X' alloy is at%, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — It is desirable that it is within the limits of 47-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.

[0082] the direction of Y which shows magnetization of said fixed magnetic layer 3 to drawing 1 by the switched connection field generated in the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3 by heat-treating — a single domain — it is —izing and fixed. in addition, when element X' of the X-Mn-X' alloy used as an antiferromagnetism layer 4 is the element of for example, a gas system Although the presentation ratio of element X' after heat treatment becomes small, or said X' may slip out out of the film completely and a presentation may become X-Mn from the presentation ratio of element X' in the phase which said element X' fell out out of the film, came out, and was formed by heat-treating If the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 in a membrane formation phase (before heat treatment) is in the disconformity condition, by heat-treating the crystal structure of said antiferromagnetism layer 4 It is possible to metamorphose into a superlattice from an irregular grid (face-centered cubic lattice) at fitness, and to acquire a large exchange anisotropy field. Moreover, the free magnetic layer 1 is arranged in the direction of illustration X by the hard bias layers 5 and 5 currently formed in the both sides.

[0083] In the single spin bulb mold thin film shown in drawing 1 , if the stationary current (sense current) is given to the free magnetic layer 1, the nonmagnetic conductive layer 2, and the fixed magnetic layer 3 from a conductive layer 8 and a field is moreover given in the direction of Y from a record medium, the magnetization direction of the free magnetic layer 1 will change from X towards the direction of Y. At this time, a lifting and electric resistance change [conduction electron] dispersion by the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3, or the interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1. Therefore, an electrical potential difference can change and a detection output can be obtained.

[0084] Drawing 2 is the sectional view showing the structure of the single spin bulb mold thin film of the 2nd operation gestalt of this invention. As shown in drawing 2 R> 2, the laminating of the substrate layer 6, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 is continuously carried out from the bottom. In addition, the antiferromagnetism layer 4 shown in drawing 2 is a X-Mn alloy (however, X) like the antiferromagnetism layer 4 shown in drawing 1 . they are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os — desirable — a PtMn alloy or a X-Mn-X' alloy (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed. In addition, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 are formed with the quality of the material explained by drawing 1 .

[0085] Also in this example, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is in the disconformity condition, and a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface serve as a face centred tetragonal lattice (henceforth a superlattice) of L10 mold.

[0086] Moreover, although priority orientation of the {111} sides of said antiferromagnetism layer 4 formed on the substrate layer 6 of Ta is carried out in the direction parallel to an interface If the fixed magnetic layer 3 is formed on said antiferromagnetism layer 4 as shown in drawing 2 , the amount of preferred orientation to the direction of an interface of the {111} sides of said fixed magnetic layer 3 will be smaller than the amount of preferred orientation of said antiferromagnetism layer 4, or will tend to become [tend] non-orientation. Thus, in drawing 2 , it is possible for the crystal orientation of said antiferromagnetism layer 4 and fixed magnetic layer 3 in an interface to differ, therefore to make interface structure into a disconformity condition more.

[0087] By the way, the antiferromagnetism layer 4 is a X-Mn alloy (however, X). the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is, as it is formed and is shown in drawing 2 When the antiferromagnetism layer 4 is formed in the bottom of the fixed magnetic layer 3, the presentation ratio of the element X of the X-Mn alloy which constitutes the antiferromagnetism layer 4 is at%, and it is desirable that it is within the limits of 44-57. If it is this within the limits, it is possible to acquire the exchange anisotropy field more than 400 (Oe). More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 46-55. If it is this within the limits, it is possible to acquire the exchange anisotropy field more than 600 (Oe).

[0088] Thus, it is because that an exchange anisotropy field can be greatly carried out to it being presentation within the limits mentioned above can enlarge the difference of the lattice constant (irregular grid) of the antiferromagnetism layer 4 before heat treatment, and the lattice constant of the fixed magnetic layer 3 and interface structure before heat treatment can be made into a disconformity condition. Therefore, by heat-treating, it becomes possible to make a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required in order to demonstrate an exchange anisotropy field from an irregular grid.

[0089] Moreover, said antiferromagnetism layer 4 is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — said X-Mn-X' alloy, when formed A part of lattice point of the

crystal lattice which is formed of a spatter, and serves as an interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or consists of elements X and Mn serves as a substitution solid solution permuted by element X'.

[0090] The lattice constant of the antiferromagnetism layer 4 which contains element X' in the film becomes large compared with the lattice constant of the antiferromagnetism layer 4 which does not contain said element X', and can maintain the interface structure of the antiferromagnetism layer 4 and the fixed magnetic layer 3 in a membrane formation phase (before heat treatment) at a disconformity condition.

[0091] In addition, by this invention, the presentation ratio of element X' occupied in the film is made into within the limits of 0.2-10 at%, and the more desirable presentation range is made into within the limits of 0.5-5 at%. Moreover, it is said presentation within the limits, element X' is formed, and the thing of a presentation ratio with Elements X and Mn within the limits of 4:6-6:4, then a larger switched connection field are acquired [a thing] for X:Mn is still more possible comparatively.

[0092] Moreover, as shown in drawing 2, when the antiferromagnetism layer 4 formed with the X-Mn-X' alloy is formed in the fixed magnetic layer 3 bottom in this invention, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is desirable that it is within the limits of 44-57. More preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 46-55.

[0093] In addition, the exchange anisotropy field which generates magnetization of the fixed magnetic layer 3 shown in drawing 2 in an interface with the antiferromagnetism layer 4 — the direction of illustration Y — a single domain — it is — izing and fixed.

[0094] As shown in drawing 2, on the free magnetic layer 1, spacing of the width of recording track Tw is vacated, and the exchange bias layer 9 (antiferromagnetism layer) is formed. In addition, this exchange bias layer 9 is a X-Mn alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os — desirable — a PtMn alloy or a X-Mn-X' alloy (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed.

[0095] The presentation ratio of the element X of a X-Mn alloy is at%, and has become within the limits of 47-57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56. In addition, this presentation range is the same as the presentation range of the antiferromagnetism layer 4 explained by drawing 1. Moreover, in the case of a X-Mn-X' alloy, the presentation ratio of element X' is at% and it is within the limits of 0.2-10, and the more desirable presentation range is at% and is within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. Furthermore, it is desirable to have become within the limits of 47-57, more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is [the presentation ratio of X+X' of a X-Mn-X' alloy is at% and] within the limits of 50-56.

[0096] Although the interface structure of the free magnetic layer 1 and the exchange bias layer 9 will be in a disconformity condition for it to be presentation within the limits mentioned above and the exchange anisotropy field more than 400 (Oe) can be acquired in an interface at least As shown in drawing 2, said exchange bias layers 9 and 9 Since it is not formed in the width-of-recording-track Tw part, it is strongly influenced by the amount of [of the free magnetic layer 1] both ends of an exchange anisotropy field, and is single-domain-ized in the direction of illustration X, and magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 is arranged with extent which reacts to an external magnetic field in the direction of illustration X at fitness.

[0097] Thus, in the formed single spin bulb mold thin film, magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 changes with the external magnetic fields of the direction of illustration Y in the direction of illustration Y from illustration X. Electric resistance changes by the relation between fluctuation of the direction of magnetization within this free magnetic layer 1, and the fixed magnetization direction (the direction of illustration Y) of the fixed magnetic layer 3, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.

[0098] Drawing 3 is the sectional view showing the structure of the dual spin bulb mold thin film of the 3rd operation gestalt of this invention. As shown and shown in drawing, the laminating of the substrate layer 6, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 is continuously carried out from the bottom. Furthermore on said free magnetic layer 1, the laminating of the nonmagnetic conductive layer 2, the fixed magnetic layer 3, the antiferromagnetism layer 4, and the protective layer 7 is carried out continuously. Moreover, the laminating of the hard bias layers 5 and 5 and the conductive layers 8 and 8 is carried out to the both sides of the multilayers from the substrate layer 6 to a protective layer 7. In addition, each class is formed with the same quality of the material as the quality of the material explained by drawing 1 and drawing 2.

[0099] As shown in drawing 3, the antiferromagnetism layer 4 currently formed below the free magnetic layer 1 The presentation ratio of the element X of the X-Mn alloy which constitutes said antiferromagnetism layer 4 is at% like [since it is formed in the bottom of the fixed magnetic layer 3] the antiferromagnetism layer 4 shown in drawing 2. It is desirable that it is within the limits of 44-57, and more preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 46-55.

[0100] Moreover, the antiferromagnetism layer 4 currently formed above the free magnetic layer 1 The presentation ratio of the element X of the X-Mn alloy which constitutes said antiferromagnetism layer 4 is at% like [since it is formed on the fixed magnetic layer 3] the antiferromagnetism layer 4 shown in drawing 1. It is desirable that it is within the limits of 47-57, and more preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56.

[0101] If it is this presentation within the limits, since the difference of the lattice constant of the fixed magnetic layer 3 and the lattice constant of the antiferromagnetism layer 4 before heat treatment can be enlarged, it is possible by being able to change the interface structure before heat treatment into a disconformity condition, therefore heat-treating to make a part of crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required to demonstrate an exchange anisotropy field from an irregular grid. In addition, the ratio of the lattice constants a and c of said antiferromagnetism layer 4 after heat treatment when said antiferromagnetism layer 4 is formed with a PtMn alloy — as for c/a, it is desirable that it is within the limits of 0.93-0.99. Moreover, since the crystal orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 also differs, it is possible to change interface structure into a disconformity condition more.

[0102] If it comes out in the presentation range mentioned above, it is possible to acquire the exchange anisotropy field more than at least 400 (Oe), but it is more possible to make large the range of the presentation ratio of the element X of a X-Mn alloy a little rather than the direction which forms the antiferromagnetism layer 4 in the bottom of the fixed magnetic layer 3 forms on

the fixed magnetic layer 3.

[0103] Moreover, when the antiferromagnetism layer 4 is formed with a X-Mn-X' alloy, the presentation ratio of element X' is at% and it is within the limits of 0.2-10, and the more desirable presentation range is at% and is within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4.

[0104] In the case of the antiferromagnetism layer 4 currently furthermore formed below the free magnetic layer 1, it is desirable that the presentation ratio of X+X' of the X-Mn-X' alloy which constitutes said antiferromagnetism layer 4 is at%, and it is within the limits of 44-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 46-55.

[0105] Moreover, in the case of the antiferromagnetism layer 4 currently formed above the free magnetic layer 1, it is desirable that the presentation ratio of X+X' of the X-Mn-X' alloy which constitutes said antiferromagnetism layer 4 is at%, and it is within the limits of 47-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.

[0106] If it is above-mentioned presentation within the limits, it is possible by being able to enlarge the difference of the lattice constant of the fixed magnetic layer 3 and the lattice constant of the antiferromagnetism layer 4 before heat treatment, and being able to change the interface structure before heat treatment into a disconformity condition, therefore heat-treating to make a part of crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required to demonstrate an exchange anisotropy field from an irregular grid.

[0107] in addition, the single spin bulb mold thin film which also shows this dual spin bulb mold thin film to drawing 1 — the same — the fixed magnetic layer 3 — an exchange anisotropy field — the direction of illustration Y — a single domain — are-izing, and it is fixed and magnetization of the free magnetic layer 1 is arranged in the direction of illustration X in response to the effect of the hard bias layers 5 and 5.

[0108] If the stationary current is given to the free magnetic layer 1, the nonmagnetic conductive layer 2, and the fixed magnetic layer 3 from a conductive layer 8 and a field is moreover given in the direction of Y from a record medium When magnetization of the free magnetic layer 1 is changed in the direction of Y from illustration X and dispersion of the conduction electron for which it depended on spin by the interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1 and the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3 at this time takes place Electric resistance changes and the leakage field from a record medium is detected.

[0109] in addition, in the single spin bulb mold thin film shown in drawing 1 and drawing 2 The location from which dispersion of the electron depending on spin is started The interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1, and by the dual spin bulb mold thin film shown in drawing 3, to being two places of the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3 Since the location where dispersion of conduction electron takes place is a total of four places of two interfaces of the nonmagnetic conductive layer 2 and the free magnetic layer 1, and two interfaces of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3, The direction of a dual spin bulb mold thin film is able to obtain large resistance rate of change compared with a single spin bulb mold thin film.

[0110] Drawing 4 is the sectional view showing the structure of the AMR mold thin film of the 4th operation gestalt of this invention. As shown in drawing, the laminating of the soft magnetism layer (SAL layer) 10, a non-magnetic layer (SHUNT layer) 11, and the magnetic-reluctance layer (MR layer) 12 is continuously carried out from the bottom. For example, said soft magnetism layer 10 is formed with a Fe-nickel-Nb alloy, and the non-magnetic layer 11 is formed for Ta film and the magnetic-reluctance layer 12 with the NiFe alloy.

[0111] On said magnetic-reluctance layer 12, the exchange bias layers (antiferromagnetism layer) 9 and 9 are formed in the part of the direction both sides of X which opened the width of recording track Tw, and the conductive layers 13 and 13 formed by Cr film etc. are further formed on said exchange bias layers 9 and 9.

[0112] the exchange bias layers 9 and 9 which show the exchange bias layers 9 and 9 shown in drawing 4 to drawing 2 — the same — a X-Mn alloy — it is preferably formed with the PtMn alloy, and the presentation ratio of the element X of an X-Mn alloy is at%, and has become within the limits of 47-57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56.

[0113] Moreover, said exchange bias layers 9 and 9 a X-Mn-X' alloy (it Au(s) and Pb(s) however, X' — Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, and Re —) and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed, and the presentation ratio of element X' is at%, and it is within the limits of 0.2-10, and it is [the more desirable presentation range is at% and] within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. Moreover, like the exchange bias layers 9 and 9 shown in drawing 2, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and the exchange bias layers 9 and 9 shown in drawing 4 have become within the limits of 47-57. More preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.

[0114] If it forms within limits which mentioned the presentation ratio of an X-Mn alloy or an X-Mn-X' alloy above By heat-treating by the interface structure of said exchange bias layers 9 and 9 and magnetic-reluctance layer 12 being in a disconformity condition When the thickness of the magnetic-reluctance layer 12 of a NiFe alloy is 200-300Å The exchange anisotropy field of about 40-110 (Oe) is acquired in said interface, and it divides. The thickness of the magnetic-reluctance layer of a NiFe alloy in the case of about 200Å The exchange anisotropy field of about 60-110 (Oe) is acquired, and area B of the magnetic-reluctance layer 12 shown in drawing 4 is single-domain-ized in the direction of illustration X. And it is induced by this and magnetization of the area A of said magnetic-reluctance layer 12 is arranged in the direction of illustration X. Moreover, the current field generated in case a detection current flows the magnetic-reluctance layer 12 is impressed to the soft magnetism layer 10 in the direction of Y, and a horizontal bias field is given to the area A of the magnetic-reluctance layer 12 in the direction of Y by the magnetostatic binding energy which the soft magnetism layer 10 brings about. By giving this horizontal bias layer to the area A of the magnetic-reluctance layer 12 single-domain-ized in the direction of X, the resistance change (magneto-resistive-effect property: the H-R effectiveness property) to field change of the area A of the magnetic-reluctance layer 12 is set as the condition of having linearity. The migration direction of a record medium is a Z direction, if a leakage field is given in the direction of illustration Y, the resistance of the area A of the magnetic-reluctance layer 12 will change, and this will be detected as electrical-potential-difference change.

[0115] As explained in full detail above, at this invention, it is a X-Mn alloy (however, X) about the antiferromagnetism layer 4 (or exchange bias layer 9). In case [which are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os] it forms with a PtMn alloy preferably, by adjusting the presentation ratio of said antiferromagnetism layer 4 to fitness It is possible

to be able to make into a disconformity condition interface structure of said antiferromagnetism layer 4 and the fixed magnetic layer 3 (or the free magnetic layer 1 or the magnetic-reluctance layer 12) formed in contact with this antiferromagnetism layer 4, therefore to be able to acquire a bigger exchange anisotropy field, and to raise reproducing characteristics compared with the former. Or it is said antiferromagnetism layer 4 (or exchange bias layer 9) as the 3rd element in addition to Elements X and Mn Element X' (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is, since the lattice constant of the antiferromagnetism layer 4 can be enlarged compared with the case where said element X' is not added by adding Interface structure of said antiferromagnetism layer 4 and the fixed magnetic layer 3 (or the free magnetic layer 1 or the magnetic-reluctance layer 12) formed in contact with this antiferromagnetism layer 4 can be made into a disconformity condition. Therefore, a bigger exchange anisotropy field can be acquired and it is possible to raise reproducing characteristics compared with the former. Moreover, it is desirable to make the crystal orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 differ at the point which interface structure can be made easier to change into a disconformity condition.

[0116] Moreover, although it is because the crystal structure of said antiferromagnetism layer 4 can be made to metamorphose into a superlattice from an irregular grid when it heat-treats that an exchange anisotropy field can be acquired by what interface structure is made into the disconformity condition for, since a problem will arise in adhesion etc. if all the crystal structures metamorphose into a superlattice, it is desirable that only a part of crystal structures are metamorphosing into the superlattice. for example, the ratio of the lattice constants a and c of said antiferromagnetism layer 4 after heat treatment when said antiferromagnetism layer 4 is formed with a PtMn alloy — it is desirable that c/a is within the limits of 0.93–0.99 (the case where all the crystal structures incidentally carry out a variant to a superlattice — the ratio of said lattice constants a and c — c/a is 0.918).

[0117] In addition, in this invention, it does not limit to the structure which shows the structure of a magneto-resistive effect component layer in drawing 1 – drawing 4. For example, without forming the hard bias layers 5 and 5 in the case of the single spin bulb mold thin film shown in drawing 1 Without forming the exchange bias layers 9 and 9 in the case of the single spin bulb mold thin film which may vacate spacing of the width of recording track Tw for the free magnetic layer 1 bottom, may form an exchange bias layer, and is shown in drawing 2 the both sides of six layers from the substrate layer 6 to a protective layer 7 — or a hard bias layer may be formed in the both sides of the free magnetic layer 1 at least.

[0118] Drawing 5 is the sectional view in which the magneto-resistive effect component layer shown in drawing 4 from drawing 1 was formed and which read and looked at the structure of a head from the opposed face side with a record medium. A sign 20 is the lower shielding layer formed for example, with the NiFe alloy etc., and the lower gap layer 21 is formed on this lower shielding layer 20. Moreover, on the lower gap layer 21, the magneto-resistive effect component layer 22 shown in drawing 4 is formed from drawing 1, further, the up gap layer 23 is formed on said magneto-resistive effect component layer 22, and the up shielding layer 24 formed with the NiFe alloy etc. is formed on said up gap layer 23.

[0119] Said lower gap layer 21 and the up gap layer 23 are formed of insulating materials, such as SiO₂ and aluminum 2O₃ (alumina). As shown in drawing 5, the die length from the lower gap layer 21 to the up gap layer 23 is gap length Gl, and it can respond to high recording density-ization, so that this gap length Gl is small.

[0120]

[Example] In this invention, the multilayers which consist of the film configuration shown below first were formed, and it investigated about the relation between the amount of Pt(s) of one element which constitutes an antiferromagnetism layer, and the lattice constant of said antiferromagnetism layer. As a film configuration, they are Si substrate / alumina / substrate layer:Ta (100) / fixed magnetic layer:NiFe (300) / antiferromagnetism layer from the bottom :P The laminating was carried out in the order of tMn (300)/Ta (100). In addition, the numeric value in the above-mentioned parenthesis expresses thickness, and a unit is angstrom. An experiment is the phase which does not heat-treat and asked for the relation between the amount of Pt(s), and the lattice constant of an antiferromagnetism layer from the peak location of a diffraction pattern by the theta / the 2theta method of an X diffraction.

[0121] It turns out that the lattice constant of an antiferromagnetism layer (PtMn) is large as are shown in drawing 6 and the amount of Pt(s) increases. Moreover, as shown in drawing, the range of the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or the lattice constant of Co is about 3.5 to 3.6.

[0122] Next, membranes were formed by the DC magnetron sputtering method, and two multilayers in which the antiferromagnetism layer was formed to the bottom of a fixed magnetic layer or a top were investigated about the relation of the amount of Pt(s) (one element which constitutes an antiferromagnetism layer) and an exchange anisotropy field after heat-treating. The experimental result is shown in drawing 7.

[0123] An antiferromagnetism layer as a film configuration currently formed in the bottom of a fixed magnetic layer Si substrate / alumina / substrate layer [from the bottom]: — Ta(50) / antiferromagnetism layer :P A laminating is carried out in the order of Ta (100). tMn (300) / fixed magnetic layer: — Co90Fe10 (30) / protective layer: — Said antiferromagnetism layer carried out the laminating from the bottom as a film configuration currently formed on the fixed magnetic layer in the order of Si substrate / alumina / Ta(50) / fixed magnetic layer:Co90Fe10 (30) / antiferromagnetism layer (300) / protective layer:Ta (100). In addition, the numeric value in the above-mentioned parenthesis expresses thickness, and a unit is angstrom.

[0124] As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent on the temperature fall again. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.

[0125] as shown in drawing 7, when [and] an antiferromagnetism layer (PtMn alloy) is in the fixed magnetic layer bottom, and when [both] it is in the bottom, the amount of Pt(s) becomes large to about 50 at(s)% — alike — following — an exchange anisotropy field — high — becoming — the amount of Pt(s) — about 50 — when it becomes more than at%, it turns out that the exchange anisotropy field is becoming small gradually.

[0126] In order to acquire the exchange anisotropy field more than 400 (Oe), when an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom and an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom for the amount of Pt(s) by 44 – 57at% of within the limits, it turns out that what is necessary is just to adjust the amount of Pt(s) to fitness by 47 – 57at% of within the limits.

[0127] Moreover, in order to acquire the exchange anisotropy field more than 600 (Oe), when an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom and an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom for the amount of Pt(s) by 46 – 55at% of within the limits, it turns out that what is necessary is just to adjust the amount of Pt(s)

to fitness by 50 - 56at% of within the limits.

[0128] From the above experimental result, four kinds of multilayers were formed as an example which adjusted the presentation ratio of an antiferromagnetism layer (PtMn) to fitness, one kind of multilayers were formed as an example of a comparison, and it investigated about a stacking tendency, an exchange anisotropy field, etc. of each film. The experimental result is shown in Table 1.

[0129]

[Table 1]

表 1

	膜構成	PtMn 組成 (at%)	PtMn/Co-Fe 界面での 格子整合	PtMn の {111} 配向	強磁性層 / Cu / 強磁性層部分の {111} 配向	240℃熱処理 後の PtMn の 規則化度	交換結合磁界, Hex (Oe)	抵抗変化率 (%)
①	基板/アルミナ/Ta (30Å) / PtMn (300Å) / Co-Fe (30Å) / Cu (22Å) / Co-Fe (10Å) / Ni-Fe (70Å) / Ta (50Å)	Pt ₅₀ Mn ₅₀	なし	中	弱	○	770	6.7
②	基板/アルミナ/PtMn (300Å) / Co (30Å) / Cu (24Å) / Ni-Fe (80Å) / Ta (50Å)	Pt ₅₀ Mn ₅₀	なし	弱	弱	○	730	4.5
③	基板/アルミナ/Ta (50Å) / Ni-Fe (70Å) / Co-Fe (10Å) / Cu (28Å) / Co-Fe (30Å) / PtMn (300Å) / Ta (50Å)	Pt ₅₀ Mn ₅₀	なし	弱	強	○	620	5.7
④	基板/アルミナ/Ta (30Å) / PtMn (200Å) / Co-Fe (30Å) / Cu (22Å) / Co-Fe (10Å) / Ni-Fe (60Å) / Co-Fe (10Å) / Cu (22Å) / Co-Fe (30Å) / PtMn (200Å) / Ta (50Å)	Pt ₅₀ Mn ₅₀	なし	中	弱	○	610	9.3
⑤	③と同一	Pt ₅₀ Mn ₅₀	有り	強	強	×	40	0.2
実施例								
比較例								

The multilayers to example ** are single spin bulb mold thin films, and the multilayers of example ** are dual spin bulb mold thin films. Moreover, the multilayers of example of comparison ** are the same film configurations as the multilayers of example **, and only the presentation ratios of an antiferromagnetism layer (PtMn) differ.

[0130] Moreover, although the laminating of Co-Fe and nickel-Fe is carried out to the multilayers of example ** on Cu (nonmagnetic conductive layer), the free magnetic layer consists of two-layer [this]. Although the laminating of nickel-Fe and Co-Fe is similarly carried out to the multilayers of example ** under Cu (nonmagnetic conductive layer), the free magnetic layer consists of two-layer [this]. Moreover, although the laminating of Co-Fe, nickel-Fe, and Co-Fe is carried out to the multilayers of example ** between two Cu(s) (nonmagnetic conductive layer), the free magnetic layer consists of these three layers.

[0131] as shown in Table 1, in the multilayers to example ** are, the lattice matching in the interface of PtMn (antiferromagnetism layer) and CoFe (fixed magnetic layer) "is nothing" — receiving — the multilayers of example of comparison ** — the lattice matching in an interface — "it is" — it has become. Moreover, if the column of "whenever [regulation-ized / of PtMn after 240 degree-C heat treatment]" is seen, by the multilayers of example of comparison **, it is "x" to being "O" in the multilayers of example ** - **.

[0132] Furthermore, when the column of an "exchange anisotropy field" and "resistance rate of change" is seen, in the multilayers to example ** are, it turns out to having a large exchange anisotropy field and resistance rate of change that the exchange anisotropy field and resistance rate of change of multilayers of example of comparison ** are very small compared with the multilayers of example ** - **.

[0133] The above experimental result is related to the presentation ratio of a PtMn alloy. As shown in Table 1, the amount of Pt (s) of PtMn to example ** is 49 - 51at% to the amount of Pt(s) of PtMn in example of comparison ** being 44at(s)%.

[0134] For this reason, when drawing 6 (before heat treatment) is referred to, it turns out that the lattice constant of PtMn of example of comparison ** is smaller than the lattice constant of PtMn to example **, and the difference of the lattice constant of PtMn (antiferromagnetism layer) and the lattice constant of Co-Fe (fixed magnetic layer) is [the direction of example of comparison **] small compared with example ** - **.

[0135] That is, in the multilayers of example of comparison **, the interface structure of PtMn and CoFe will tend to be in an adjustment condition, and, on the other hand, the interface structure of PtMn and CoFe will be easy to be in a disconformity condition in the phase before heat treatment by the multilayers to example ** - **.

[0136] Before heat treatment, although the crystal structure of PtMn of example ** and example of comparison ** serves as an irregular grid (face-centered cubic lattice), even if it heat-treats, the crystal structure of PtMn cannot metamorphose into a superlattice from an irregular grid, but regulation-ization is in the condition of not progressing at all, by example of comparison ** from which interface structure is in the adjustment condition.

[0137] On the other hand, in the multilayers of example ** from which interface structure is in the disconformity condition - **, by heat-treating, a part metamorphoses into a superlattice (face centred tetragonal lattice of L10 mold) from an irregular grid, and the crystal structure of PtMn has become that to which regulation-ization fully advanced.

[0138] Drawing 8 is a high-resolution TEM photograph in which the interface structure of PtMn of example ** and CoFe after heat treatment is shown. As shown in drawing 8, in the interface of PtMn and CoFe, it turns out that the direction of a list of the atom of PtMn and the direction of a list of the atom of CoFe are not in agreement, and it is in a disconformity condition.

[0139] On the other hand, drawing 9 is a high-resolution TEM photograph in which the interface structure of PtMn of example of comparison ** and CoFe after heat treatment is shown. As shown in drawing 9, in the interface of PtMn and CoFe, it turns out that the direction of a list of the atom of PtMn and the direction of a list of the atom of CoFe are in agreement, and it is in an adjustment condition.

[0140] Moreover, drawing 10 is an experimental result after heat treatment to which drawing 11 measured whenever [regulation-ized / of PtMn / in / for whenever / regulation-ized / of PtMn in the multilayers of example ** / the multilayers of example of comparison **]. The experiment measured the include angle which two equivalent {111} sides in PtMn make, and asked for whenever [regulation-ized] from the include angle to make. In addition, the axis of abscissa shows the distance from the interface of PtMn and CoFe to the PtMn side.

[0141] As shown in drawing 10, the measured value of the include angle which {111} sides make is scattered within the limits of about 65 to about 72 degrees, and it turns out that a part of irregular grid before heat treatment changes, and the crystal structure of PtMn serves as a superlattice.

[0142] On the other hand, in drawing 11, the measured value of the include angle which {111} sides make has fallen within about 70 - about 71 range, and even if the crystal structure of PtMn heat-treats, it turns out that it has meant having maintained the condition of the irregular grid before heat treatment with as.

[0143] As mentioned above, in the multilayers of example ** - **, since interface structure can be made into a disconformity condition, therefore regulation-ization can be advanced to fitness by making the amount of Pt(s) of PtMn into 49 - 51at%, the exchange anisotropy field generated in the interface of PtMn and CoFe has the very large value so that it may understand, even if it sees drawing 7.

[0144] On the other hand, in the multilayers of example of comparison **, since the amount of Pt(s) of PtMn is as low as 44at (s)%, the exchange anisotropy field which generates interface structure in the interface of PtMn and CoFe so that it may understand, even if it will be in an adjustment condition, regulation-ization does not progress to fitness but it sees drawing 7 will become a very small value. Moreover, in order to make interface structure of PtMn and CoFe into a disconformity condition, it is desirable to make the crystal orientation of PtMn and the crystal orientation of CoFe differ.

[0145] In addition, a little more than [of the amount of preferred orientation of the {111} sides shown in Table 1 / "a little more than"], "inside", and "weakness" express the priority amount of preferred orientation to the direction of a film surface. As shown in Table 1, both the amount of preferred orientation of the {111} sides of PtMn of example of comparison ** and the amount of preferred orientation of the {111} sides of CoFe (fixed magnetic layer) are ["a little more than"].

[0146] If this refers to the film configuration of example **, NiFe, CoFe (free magnetic layer), Cu (nonmagnetic conductive layer), and CoFe (fixed magnetic layer) which were formed on Ta. Since the difference of the lattice constant of CoFe (fixed magnetic layer) and the lattice constant of PtMn (antiferromagnetism layer) before heat treatment is small so that the amount of preferred orientation of {111} sides may become strong in response to the effect of Ta as a substrate layer and it may understand with reference to drawing 6 strongly. Strongly in response to the fact that the effect of the amount of preferred orientation of the {111} sides of CoFe, priority orientation of the {111} sides of PtMn will be carried out in the direction of a film surface.

[0147] On the other hand, NiFe, CoFe (free magnetic layer), Cu (nonmagnetic conductive layer), and CoFe (fixed magnetic layer)

which were formed on Ta in example **. Although the amount of preferred orientation of {111} sides becomes strong strongly in response to the fact that the effect of Ta as a substrate layer Since the difference of the lattice constant of CoFe (fixed magnetic layer) and the lattice constant of PtMn (antiferromagnetism layer) before heat treatment is large so that it may understand with reference to drawing 6, the {111} sides of PtMn are seldom influenced of the crystal orientation of CoFe, but the amount of preferred orientation in the direction of a film surface is weak.

[0148] Moreover, in the case where it is example **** by which the laminating of the CoFe (fixed magnetic layer) is carried out on PtMn, if CoFe is formed on PtMn, the amount of preferred orientation of the {111} sides of CoFe will become weak, therefore the crystal orientation of PtMn and CoFe will be turned in the automatically different direction.

[0149] Next, in this invention, the antiferromagnetism layer was formed with the Pt-Mn-X' (X'=Ar) alloy, and it investigated about the relation between the amount of element X', and the lattice constant of a Pt-Mn-X' alloy. The film configurations used for the experiment are Si substrate / alumina / Ta(50) / Co90Fe10 (30) / Pt-Mn-X' (300) / Ta from the bottom (100). In addition, the numeric value in a parenthesis expresses thickness and a unit is angstrom.

[0150] In the sputtering system, membrane formation of an antiferromagnetism layer prepared three kinds of targets with which the rate of Pt and Mn is set to 6:4, 5:5, and 4:6, and it formed the Pt-Mn-X' (X'=Ar) alloy film by DC magnetron sputtering and the ion beam spatter, changing the introductory gas pressure of Ar which becomes element X' using each target. And it measured about the relation between the amount of X' (X'=Ar) occupied in the Pt-Mn-X' (X'=Ar) alloy film, and the lattice constant of Pt-Mn-X' (X'=Ar). The experimental result is shown in drawing 12.

[0151] As shown in drawing 12, when [of the presentation ratio of Pt and Mn] the amount of element X' (X'=Ar) becomes large in the case of either 6:4, 5:5 and 4:6 shows comparatively that the lattice constant of Pt-Mn-X' (X'=Ar) becomes large. In addition, the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or Co As shown in drawing 12, the range of a lattice constant is about 3.5 to 3.6. Moreover, although the amount of element X' (X'=Ar) is carried out to to about 4at% and the experiment is not tried about the case of a large content any more in this experiment, since it is a gas element, Ar from which this becomes element X' is because it is hard to contain Ar in the film, even if it raises gas pressure.

[0152] Next, the heat treatment process indicated below was given to the Pt-Mn-X' (X'=Ar) alloy film used for the above-mentioned experiment. As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then, the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent on the temperature fall. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.

[0153] Drawing 13 is a graph which shows the relation between the amount of element X' (X'=Ar) of the Pt-Mn-X' (X'=Ar) alloy film, and the magnitude of the switched connection field generated in the interface of an antiferromagnetism layer and a fixed magnetic layer by said heat treatment. As shown in drawing 13, when the amount of element X' (X'=Ar) becomes large, it turns out that the switched connection field is large. That is, if element X' (X'=Ar) is added to PtMn, it is possible to acquire a large switched connection field compared with the case where element X' (X'=Ar) is not added.

[0154] Next, in this invention, using another element X', the antiferromagnetism layer was formed with the Pt-Mn-X' (X'=Mo) alloy, and it investigated about the relation between the amount of element X' (X'=Mo), and the lattice constant of the Pt-Mn-X' (X'=Mo) alloy film. The film configurations used for the experiment are Si substrate / alumina / Ta(50) / Co90Fe10 (30) / Pt-Mn-X' (300) / Ta from the bottom (100). In addition, the numeric value in a parenthesis expresses thickness and a unit is angstrom.

[0155] The compound-die target which stuck the chip of element X' (X'=Mo) on the target of PtMn was prepared for membrane formation of an antiferromagnetism layer, and changing the surface ratio of the chip occupied at a target, the amount of element X' (X'=Mo) occupied in the film was changed, and it measured about the relation between said amount of element X' (X'=Mo), and the lattice constant of a Pt-Mn-X' (X'=Mo) alloy. The experimental result is shown in drawing 14.

[0156] It turns out that the lattice constant of Pt-Mn-X' (X'=Mo) becomes large, so that the concentration of element X' (X'=Mo) which the rate of the presentation ratio of Pt and Mn occupies in the film in one case of 6:4, 1:1, and 4:6 becomes large, as shown in drawing 14. In addition, as shown in drawing 14, the range of the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or the lattice constant of Co is about 3.5 to 3.6.

[0157] Next, the heat treatment process indicated below was given to the Pt-Mn-X' (X'=Mo) alloy film used in the above-mentioned experiment. As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then, the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent on the temperature fall. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.

[0158] Drawing 15 is a graph which shows the relation between the concentration of element X' (X'=Mo) of the Pt-Mn-X' (X'=Mo) alloy film, and the magnitude of the switched connection field generated in the interface of an antiferromagnetism layer and a fixed magnetic layer by said heat treatment. If the amount of element X' (X'=Mo) in the film becomes more than abbreviation 3at% even if the presentation ratio of Pt and Mn is which [of 6:4, 1:1, and 4:6] case comparatively as shown in drawing 15, it turns out that a switched connection field falls gradually. especially — the amount of element X' (X'=Mo) in the film — about 10 — if it becomes more than at%, even if it is the case where the rate of the presentation ratio of Pt and Mn is 1:1, a switched connection field becomes very small and is not desirable.

[0159] By the way, at least, although it is a fitness element X' (X'=Mo) content, when it does not contain said element X' (X'=Mo), it is more desirable than the time of the amount of element X' (X'=Mo) being 0at% that a switched connection field becomes large. Comparatively, in the case of 6:4, if the amount of element X' (X'=Mo) is less than [abbreviation 1at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn. Moreover, comparatively, in the case of 1:1, if the amount of element X' (X'=Mo) is less than [abbreviation 7at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn. Furthermore, comparatively, in the case of 4:6, if the amount of element X' (X'=Mo) is less than [abbreviation 10at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn.

[0160] next — although it is the minimum of a fitness element X' (X'=Mo) content — the presentation ratio of Pt:Mn — since the switched connection field became the largest comparatively when the amount of element X' (X'=Mo) became about 0.5 at(s)% in the case of 6:4, by this invention, the amount of element X' (X'=Mo) set up 0.2at(s)% smaller than 0.5at% as a minimum there.

[0161] By this invention, the desirable range of the presentation ratio of element X' was set to 0.2 to 10 at at% from the above experimental result. Moreover, the more desirable range was set to 0.5 to 5 at at%. In addition, the desirable presentation range of above-mentioned element X' is the case where Mn is set up within the limits of Pt (= element X) and 4:6 to 6:4.

[0162]

[Effect of the Invention] It sets on the switched connection film which consists of an antiferromagnetism layer and a ferromagnetic layer according to this invention explained in full detail above, and is said antiferromagnetism layer X-Mn (however, X) When forming, the presentation ratio of said antiferromagnetism layer is adjusted to fitness. the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — Since interface structure of said antiferromagnetism layer and ferromagnetic layer (for example, NiFe alloy) is made into the disconformity condition, it is possible to acquire a larger exchange anisotropy field.

[0163] Or at this invention, it is element X' (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — by making it dissolve with an invasion mold or a permutation mold in the X-Mn alloy film It is possible for the interface structure of said antiferromagnetism layer and ferromagnetic layer (for example, NiFe alloy) to change into a disconformity condition, and to acquire a larger exchange anisotropy field.

[0164] moreover, the phase which heat-treated — setting — a part of [at least] crystal structures of said antiferromagnetism layer — the face centred tetragonal lattice (superlattice) of L10 mold — becoming — **** — moreover — the ratio of the lattice constants a and c of said antiferromagnetism layer — it is desirable that c/a is within the limits of 0.93-0.99 at the point that a larger exchange anisotropy field can be acquired. Furthermore, it is desirable that the crystal orientation of said antiferromagnetism layer and ferromagnetic layer in an interface differs at the point which is easy to change interface structure into a disconformity condition.

[0165] As mentioned above, by applying the switched connection film with which interface structure is in the disconformity condition to a magneto-resistive effect component, the resistance rate of change of said magneto-resistive effect component layer can be raised, and it is possible to raise reproducing characteristics.

[Translation done.]

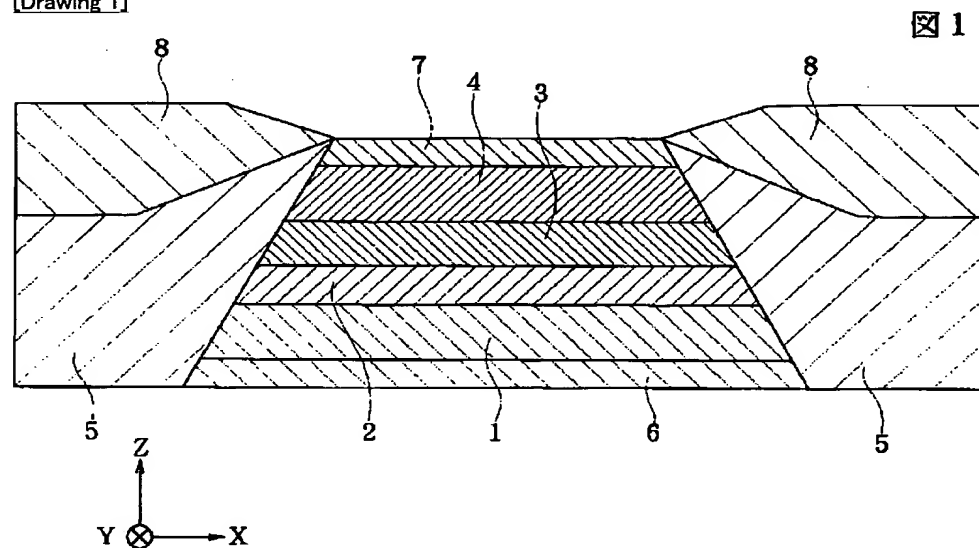
* NOTICES *

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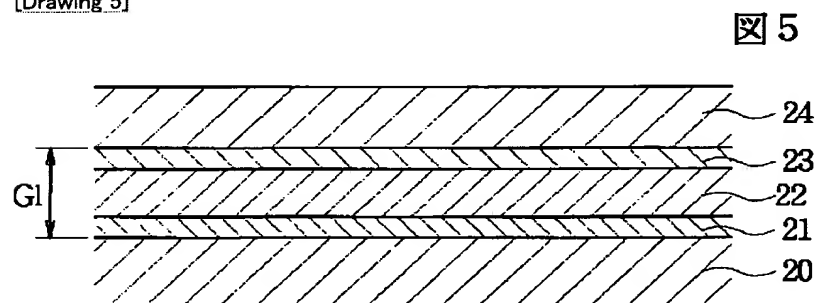
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DRAWINGS

[Drawing 1]

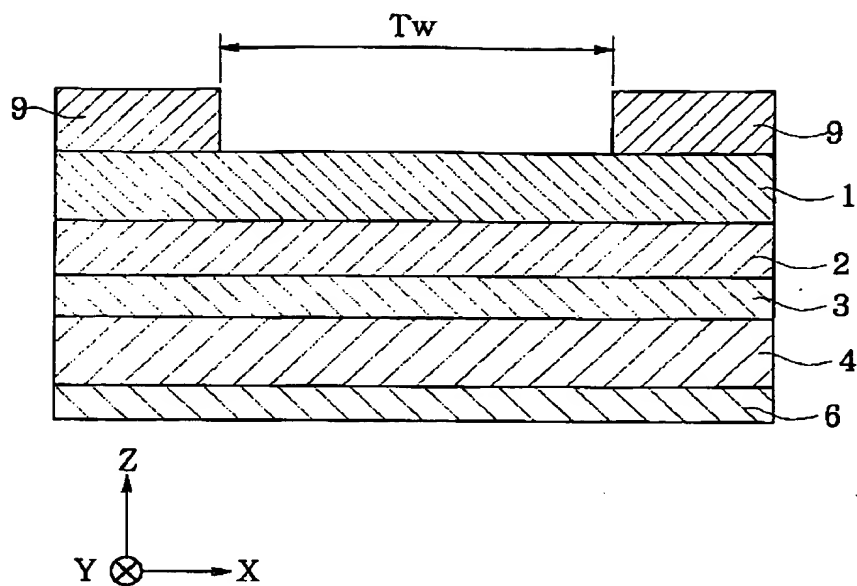


[Drawing 5]



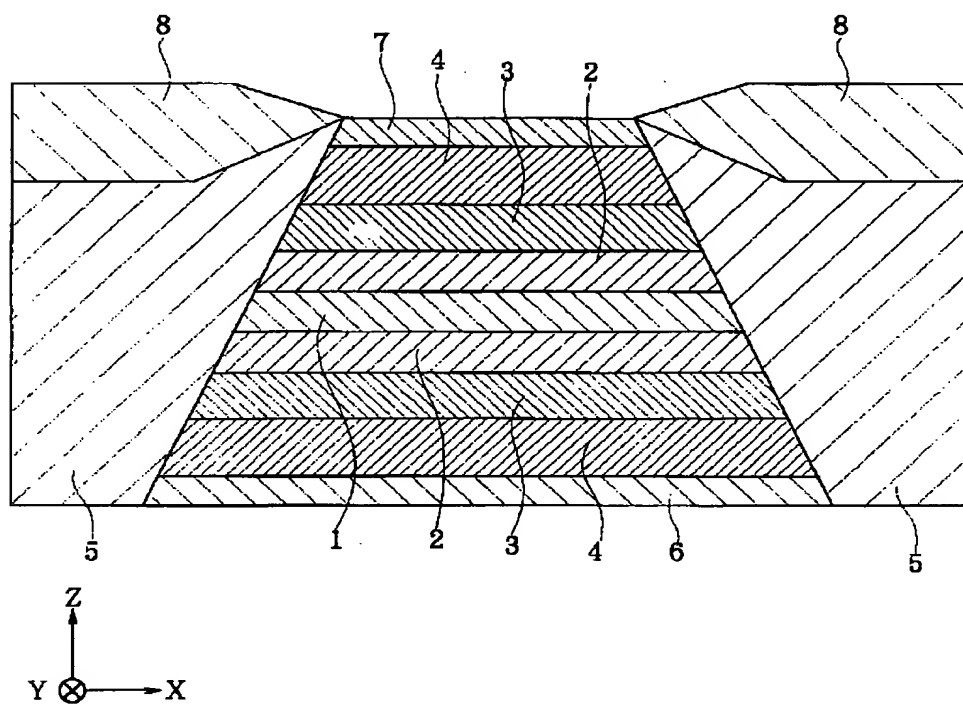
[Drawing 2]

図 2



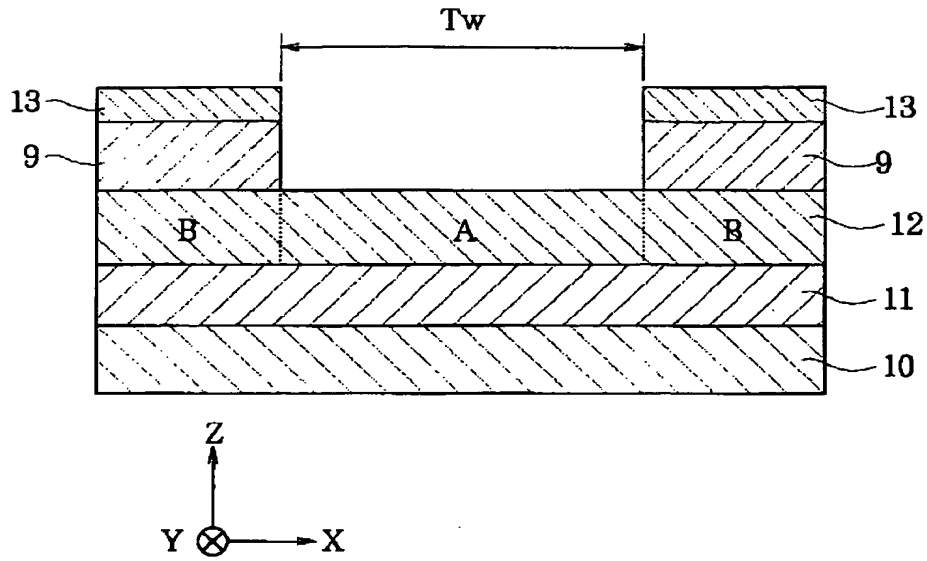
[Drawing 3]

図 3



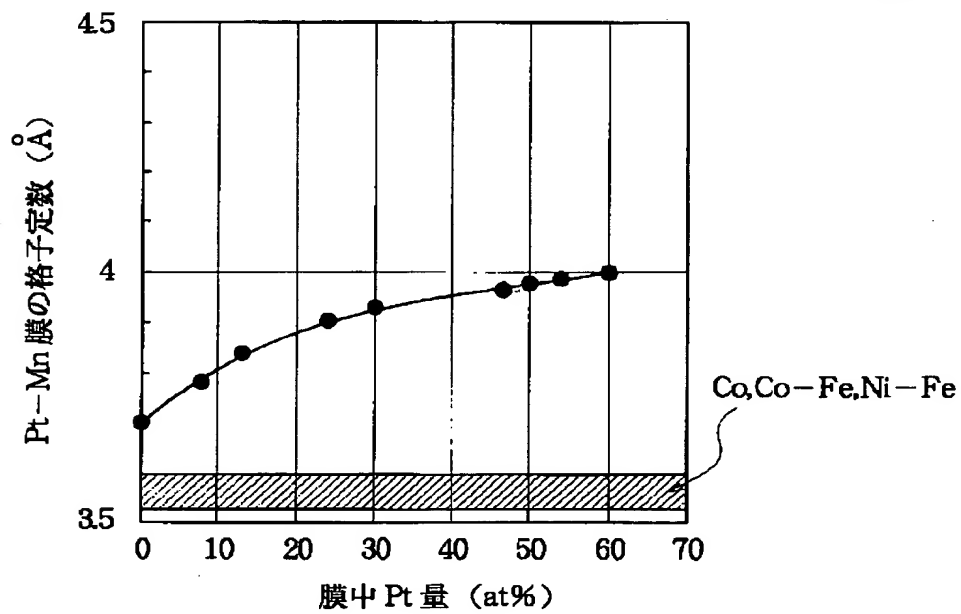
[Drawing 4]

図 4



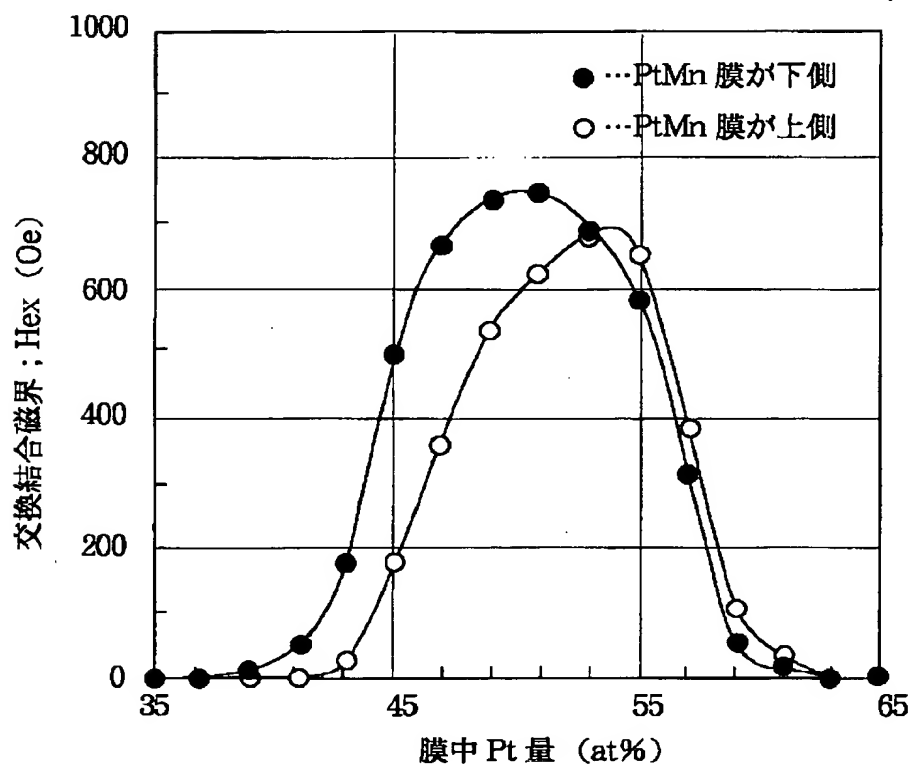
[Drawing 6]

図 6



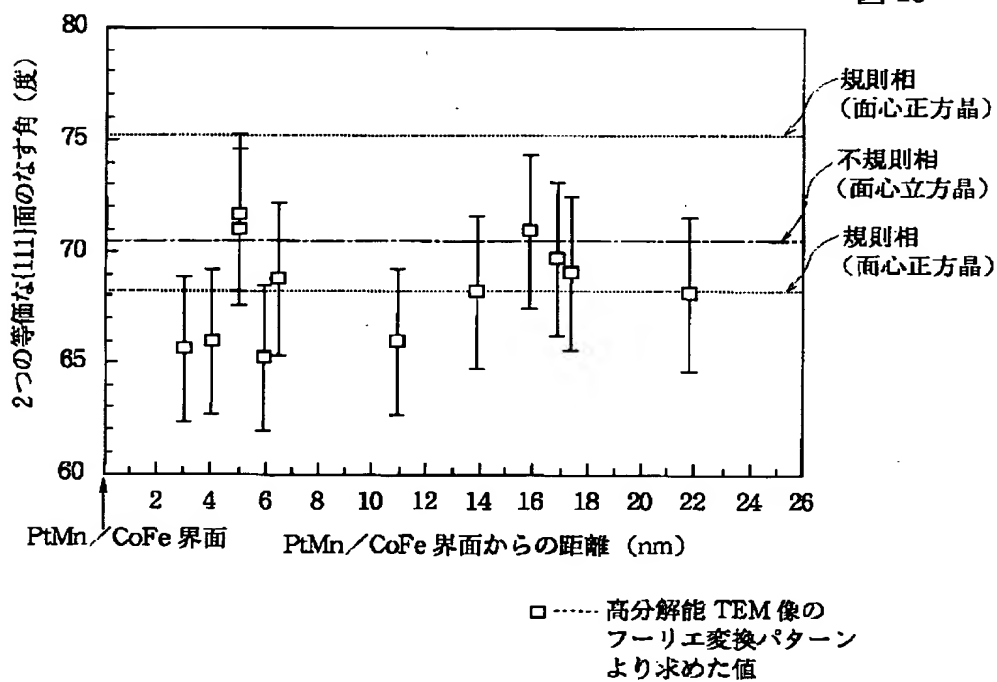
[Drawing 7]

図 7

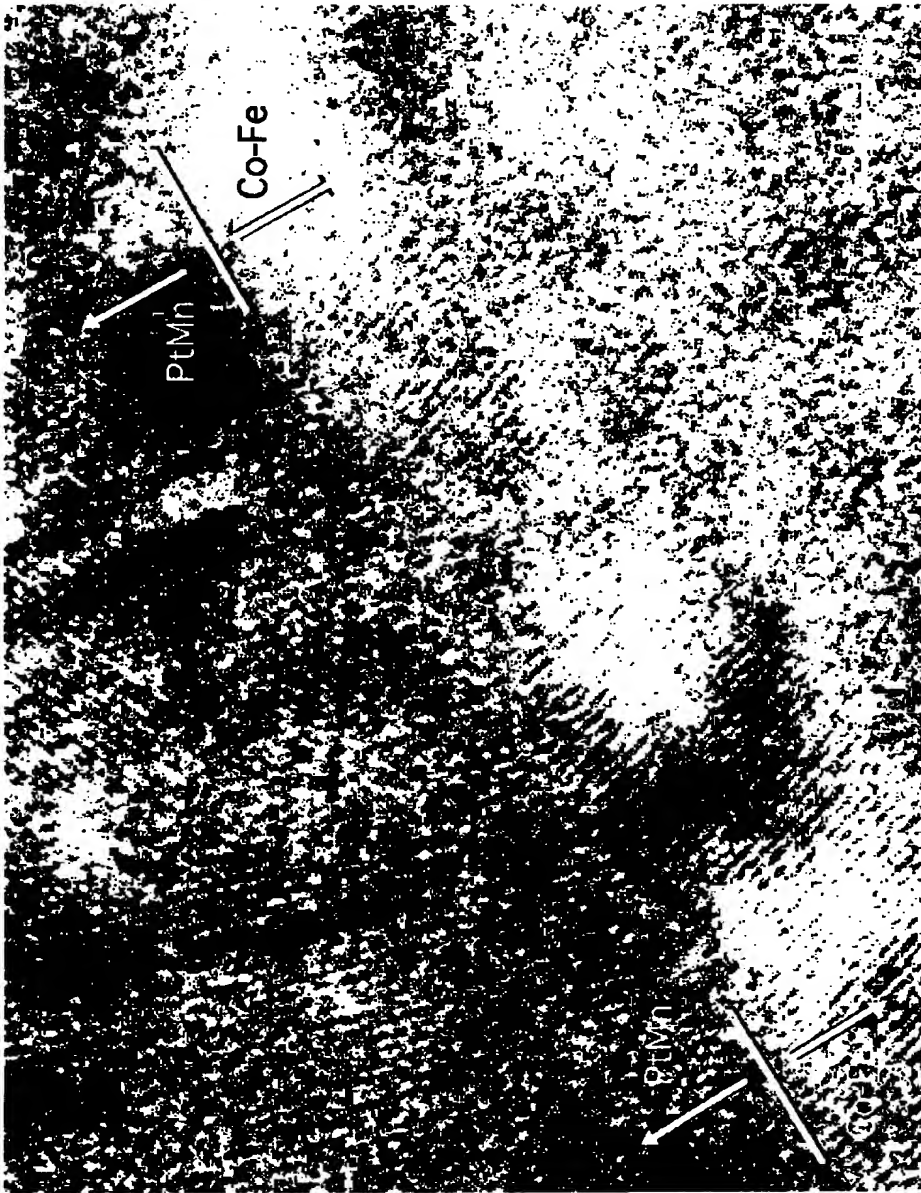


[Drawing 10]

図 10



[Drawing 8]



8



[Drawing 9]

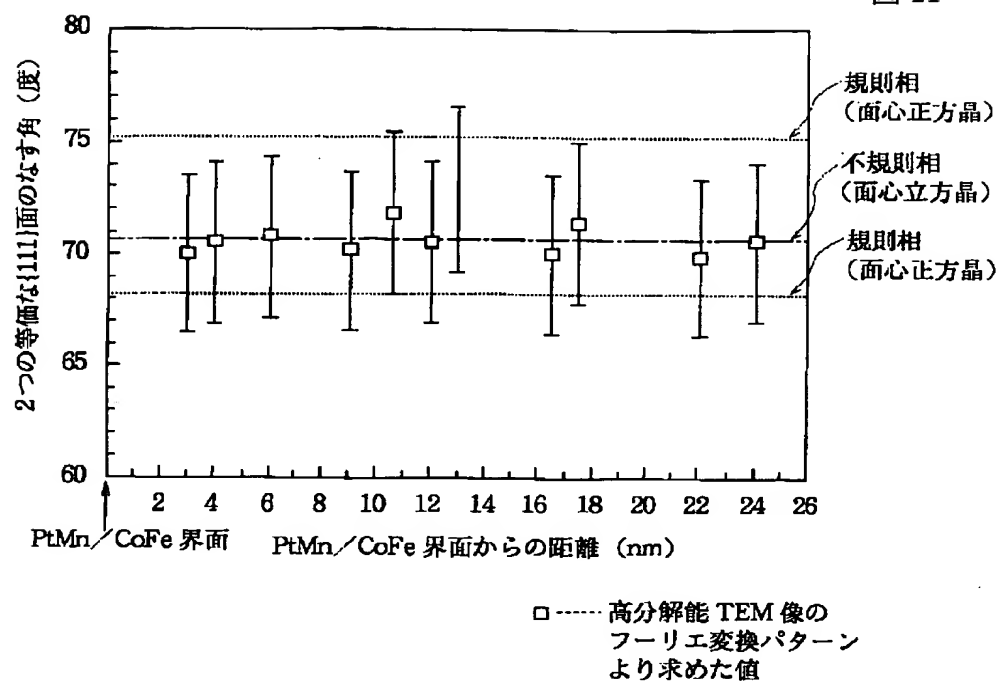


9



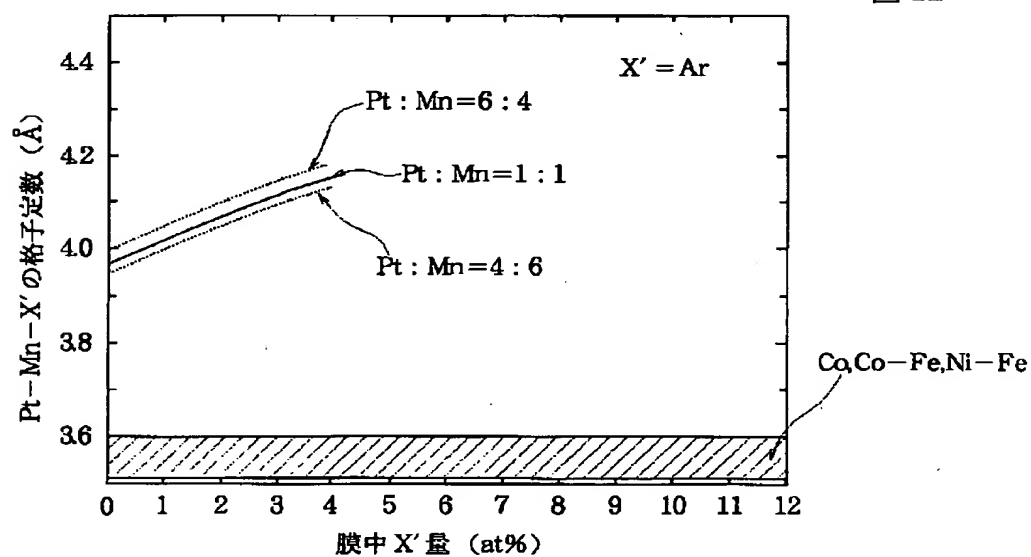
[Drawing 11]

図 11



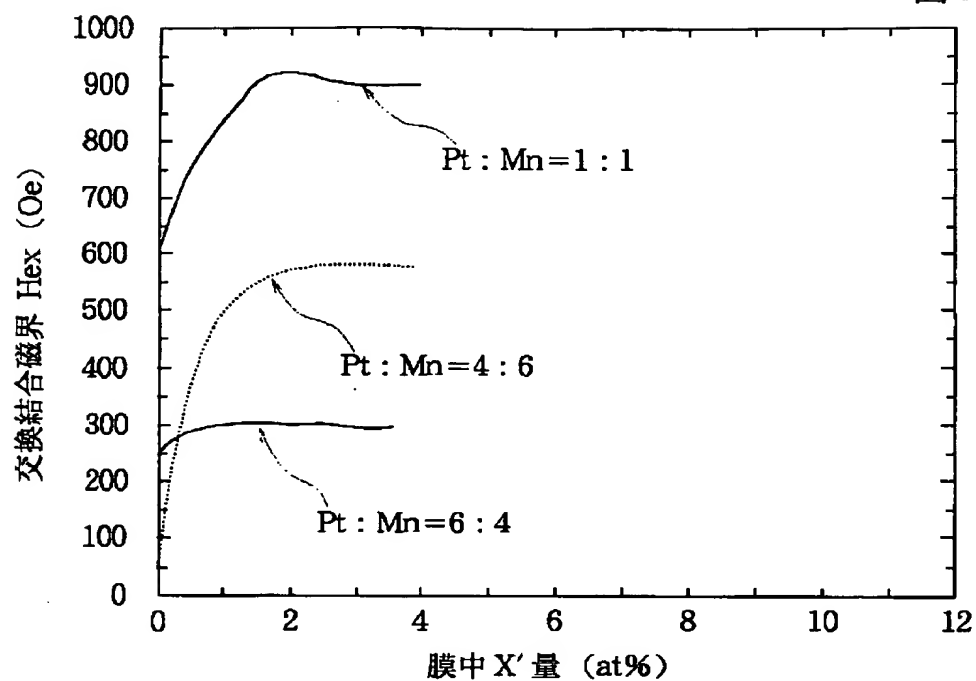
[Drawing 12]

図 12



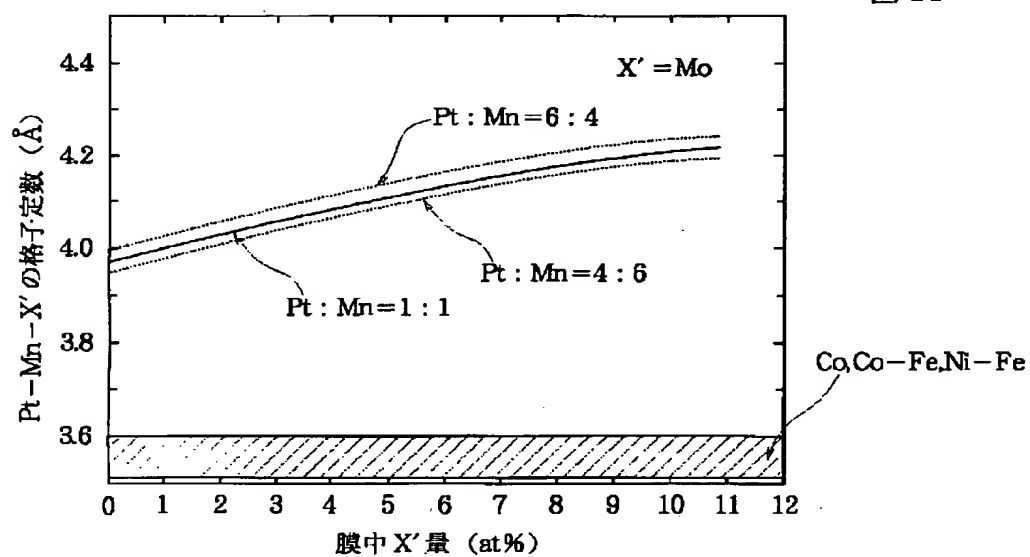
[Drawing 13]

図 13



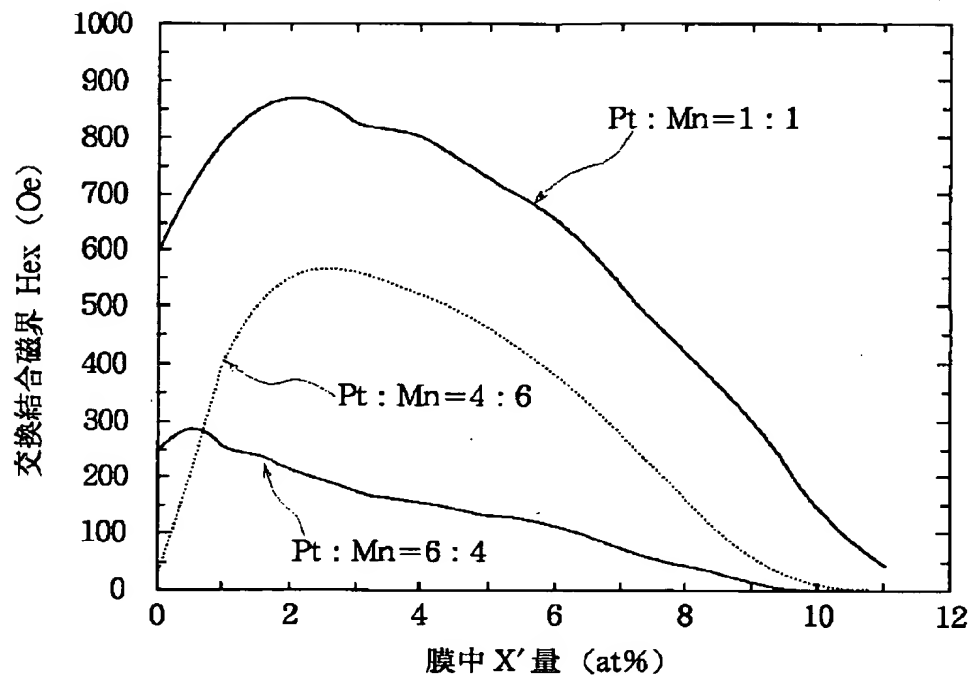
[Drawing 14]

図 14



[Drawing 15]

図 15



[Translation done.]

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 [Filing Date] April 30, Heisei 11 (1999. 4.30)
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 [Item(s) to be Amended] The name of invention
 [Method of Amendment] Modification
 [Proposed Amendment]
 [Title of the Invention] Switched connection film
 [Procedure amendment 3]
 [Document to be Amended] Specification
 [Item(s) to be Amended] Claim
 [Method of Amendment] Modification
 [Proposed Amendment]
 [Claim(s)]

[Claim 1] In the switched connection film with which an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, an exchange anisotropy field occurs in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is carried out in the fixed direction Said antiferromagnetism layer is Element X (however, X) at least, the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — the switched connection film characterized by being formed with the antiferromagnetism ingredient containing Mn and the interface structure of said antiferromagnetism layer and ferromagnetic layer being in a disconformity condition.

[Claim 2] Switched connection film according to claim 1 with which a part of [at least] crystal structures of said antiferromagnetism layer serve as a face-centered square superlattice of L10 mold.

[Claim 3] Switched connection film according to claim 1 or 2 with which the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer differs in the interface of said antiferromagnetism layer and ferromagnetic layer.

[Claim 4] The amount of preferred orientation of the {111} sides of said antiferromagnetism layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said ferromagnetic layer, or serves as non-orientation to the {111} sides of said ferromagnetic layer carrying out priority orientation in the direction parallel to an interface with said antiferromagnetism layer.

[Claim 5] The amount of preferred orientation of the {111} sides of said ferromagnetic layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said antiferromagnetism layer, or serves as non-orientation to the {111} sides of said antiferromagnetism layer carrying out priority orientation in the direction parallel to an interface with said ferromagnetic layer.

[Claim 6] Both the amount of preferred orientation of the {111} sides of said antiferromagnetism layer to a direction parallel to the interface of said antiferromagnetism layer and ferromagnetic layer and the amount of preferred orientation of the {111} sides of said ferromagnetic layer are switched connection film according to claim 3 with which it is small, or has become non-orientation, priority orientation of the crystal faces other than the aforementioned {111} sides is carried out in the direction parallel to an interface, and the crystal orientation of an antiferromagnetism layer and a ferromagnetic layer differs.

[Claim 7] It is the switched connection film according to claim 1 to 6 whose element X said antiferromagnetism layer is formed with a X-Mn alloy, and is Pt.

[Claim 8] said antiferromagnetism layer is formed with a PtMn alloy — having — the ratio of the lattice constants a and c of said antiferromagnetism layer — the switched connection film according to claim 7 whose c/a is within the limits of 0.93-0.99.

[Claim 9] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). It is formed. the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — said X-Mn-X' alloy Switched connection film according to claim 1 to 6 a part of whose lattice point of the crystal lattice which consists of elements X and Mn it is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or is the substitution solid solution permuted by element X'.

[Claim 10] The element X of the X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 which is Pt.

[Claim 11] Said element X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, And switched connection film according to claim 9 or 10 which is one sort or two sorts or more of elements among rare earth elements.

[Claim 12] Said element X' is switched connection film according to claim 11 which is one sort or two sorts or more of elements among Ne, Ar, Kr, and Xe.

[Claim 13] The presentation ratio of said element X' is switched connection film according to claim 9 to 12 which is at% and is within the limits of 0.2-10.

[Claim 14] The presentation ratio of said element X' is switched connection film according to claim 13 which is at% and is within the limits of 0.5-5.

[Claim 15] X:Mn is switched connection film of a presentation ratio with Elements X and Mn according to claim 13 or 14 which is within the limits of 4:6-6:4 comparatively.

[Claim 16] The X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 to 15 formed of a spatter.

[Claim 17] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 47-57.

[Claim 18] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 47-57.

[Claim 19] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 17 or 18 which is at% and is within the limits of 50-56.

[Claim 20] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 44-57.

[Claim 21] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 44-57.

[Claim 22] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 20 or 21 which is at% and is within the limits of 46-55.

[Procedure amendment 4]

[Document to be Amended] Specification

[Item(s) to be Amended] 0001

[Method of Amendment] Modification

[Proposed Amendment]

[0001]

[Field of the Invention] By the exchange anisotropy field which this invention consists of an antiferromagnetism layer and a ferromagnetic layer, and is generated in the interface of said antiferromagnetism layer and ferromagnetic layer When formed with the antiferromagnetism ingredient with which the switched connection film with which the magnetization direction of said ferromagnetic layer is fixed in the fixed direction is started, especially said antiferromagnetism layer contains Elements X (Pt, Pd, etc.) and Mn, it is related with the switched connection film which enabled it to acquire a larger exchange anisotropy field.

[Procedure amendment 5]

[Document to be Amended] Specification

[Item(s) to be Amended] 0004

[Method of Amendment] Modification

[Proposed Amendment]

[0004] Generally the Co-Pt (cobalt-platinum) alloy film etc. is used for Cu (copper) film and a bias layer by the Fe-Mn (iron-manganese) alloy film or the nickel-Mn (nickel-manganese) alloy film, the fixed magnetic layer, and the free magnetic layer at the nickel-Fe (nickel-iron) alloy film and a nonmagnetic conductive layer at said antiferromagnetism layer.

[Procedure amendment 6]

[Document to be Amended] Specification

[Item(s) to be Amended] 0016

[Method of Amendment] Modification

[Proposed Amendment]

[0016] This invention is for solving the above-mentioned conventional technical problem, and when the antiferromagnetism ingredient containing Elements X (X is platinum group metals) and Mn is used as an antiferromagnetism layer, it relates to the switched connection film which enabled it to generate a large exchange anisotropy field.

[Procedure amendment 7]

[Document to be Amended] Specification

[Item(s) to be Amended] 0017

[Method of Amendment] Modification

[Proposed Amendment]

[0017]

[Means for Solving the Problem] In the switched connection film with which an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, an exchange anisotropy field generates this invention in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is carried out in the fixed direction Said antiferromagnetism layer is Element X (however, X) at least the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — it is formed with the antiferromagnetism ingredient containing Mn, and interface structure of said antiferromagnetism layer and ferromagnetic layer is characterized by being in a disconformity condition.

[Procedure amendment 8]

[Document to be Amended] Specification

[Item(s) to be Amended] 0018

[Method of Amendment] Modification

[Proposed Amendment]

[0018] Moreover, it is desirable that a part of [at least] crystal structures of said antiferromagnetism layer serve as a face-centered square superlattice of L10 mold. It is desirable that the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer furthermore differs according to the interface of said antiferromagnetism layer and ferromagnetic layer by this invention.

[Procedure amendment 9]

[Document to be Amended] Specification

[Item(s) to be Amended] 0022

[Method of Amendment] Modification

[Proposed Amendment]

[0022] Moreover, in this invention, said antiferromagnetism layer is formed with a X-Mn alloy, and, as for Element X, it is desirable that it is Pt. furthermore, the case where said antiferromagnetism layer is formed with a PtMn alloy — the ratio of the lattice constants a and c of said antiferromagnetism layer — as for c/a, it is desirable that it is within the limits of 0.93-0.99.

[Procedure amendment 10]

[Document to be Amended] Specification

[Item(s) to be Amended] 0033

[Method of Amendment] Deletion

[Procedure amendment 11]

[Document to be Amended] Specification

[Item(s) to be Amended] 0034

[Method of Amendment] Deletion

[Procedure amendment 12]

[Document to be Amended] Specification

[Item(s) to be Amended] 0035

[Method of Amendment] Deletion

[Procedure amendment 13]

[Document to be Amended] Specification

[Item(s) to be Amended] 0036

[Method of Amendment] Deletion

[Procedure amendment 14]

[Document to be Amended] Specification

[Item(s) to be Amended] 0053

[Method of Amendment] Deletion

[Procedure amendment 15]

[Document to be Amended] Specification

[Item(s) to be Amended] 0054

[Method of Amendment] Deletion

[Procedure amendment 16]

[Document to be Amended] Specification

[Item(s) to be Amended] 0146

[Method of Amendment] Modification

[Proposed Amendment]

[0146] If this refers to the film configuration of example of comparison **, NiFe, CoFe (free magnetic layer), Cu (nonmagnetic conductive layer), and CoFe (fixed magnetic layer) which were formed on Ta Since the difference of the lattice constant of CoFe (fixed magnetic layer) and the lattice constant of PtMn (antiferromagnetism layer) before heat treatment is small so that the amount of preferred orientation of {111} sides may become strong in response to the effect of Ta as a substrate layer and it may understand with reference to drawing 6 strongly Strongly in response to the fact that the effect of the amount of preferred orientation of the {111} sides of CoFe, priority orientation of the {111} sides of PtMn will be carried out in the direction of a film surface.

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(74) 代理人 弁理士 野▲崎▼ 照夫

最終頁に続く

(54) 【発明の名称】 交換結合膜と、この交換結合膜を用いた磁気抵抗効果素子、ならびに、前記磁気抵抗効果素子を用いた薄膜磁気ヘッド

(57) 【要約】

【目的】 従来、反強磁性層として使用されていたNi Mn合金の場合、固定磁性層（例えばNi Fe合金）との界面構造を整合状態としておいても、適性な交換異方性磁界を得ることができるが、Ni Mn合金よりも優れた反強磁性材料である白金族元素を用いたX-Mn合金の場合、固定磁性層との界面構造を整合状態とすると、交換異方性磁界を得ることができないという問題点があった。

【構成】 反強磁性層4はX-Mn（Xは白金族元素）で形成され、Xの組成比が適性に調節されることにより、固定磁性層3との界面構造は非整合状態にされている。従って熱処理を施すことにより、前記反強磁性層4の結晶構造が変態し、大きな交換異方性磁界を得ることができるので、従来に比べてより再生特性を向上させることが可能である。

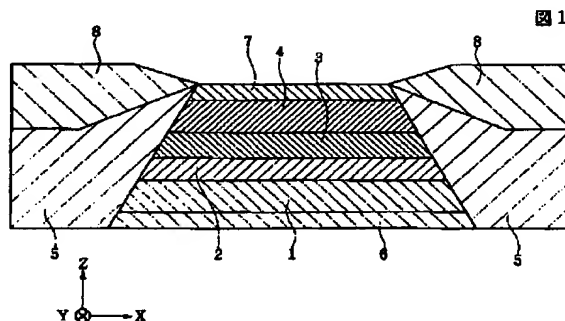


図1

【特許請求の範囲】

【請求項1】 反強磁性層と強磁性層とが接して形成され、熱処理が施されることにより、前記反強磁性層と強磁性層との界面にて交換異方性磁界が発生し、前記強磁性層の磁化方向が一定方向に固定される交換結合膜において、前記反強磁性層は、少なくとも元素X（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）とMnとを含有する反強磁性材料で形成され、前記反強磁性層と強磁性層との界面構造が、非整合状態にあることを特徴とする交換結合膜。

【請求項2】 熱処理後における前記反強磁性層の少なくとも一部の結晶構造が、L1₂型の面心正方規則格子となる請求項1記載の交換結合膜。

【請求項3】 前記反強磁性層と強磁性層との界面にて、前記反強磁性層および強磁性層の結晶配向が異なっている請求項1または2に記載の交換結合膜。

○【請求項4】 前記強磁性層の{111}面が、前記反強磁性層との界面に平行な方向に優先配向するのに対し、前記反強磁性層の{111}面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となっている請求項3記載の交換結合膜。

○【請求項5】 前記反強磁性層の{111}面が、前記強磁性層との界面に平行な方向に優先配向するのに対し、前記強磁性層の{111}面の配向度は、前記反強磁性層の配向度よりも小さいか、あるいは無配向となっている請求項3記載の交換結合膜。

【請求項6】 前記反強磁性層と強磁性層との界面に平行な方向への、前記反強磁性層の{111}面の配向度、および前記強磁性層の{111}面の配向度は共に小さくなっているか、あるいは無配向となっており、前記{111}面以外の結晶面が、界面に平行な方向へ優先配向されて、反強磁性層と強磁性層の結晶配向が異なる請求項3記載の交換結合膜。

【請求項7】 前記反強磁性層はX-Mn合金で形成され、元素Xは、Ptである請求項1ないし6のいずれかに記載の交換結合膜。

【請求項8】 前記反強磁性層はPtMn合金で形成され、熱処理後における前記反強磁性層の格子定数a、cの比c/aは、0.93~0.99の範囲内である請求項7記載の交換結合膜。

【請求項9】 前記反強磁性層は、X-Mn-X'合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）で形成され、前記X-Mn-X'合金は、元素XとMnとで構成される空間格子の隙間に元素X'が侵入した侵入型固溶体であり、あるいは、元素XとMnとで構成される結晶格子の格子点の一部が、元素X'に置換された置換型固溶体である請求項1ないし6のいずれかに記載の交換結合膜。

【請求項10】 前記反強磁性層として用いられるX-Mn-X'合金の元素XはPtである請求項9記載の交換結合膜。

【請求項11】 前記元素X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である請求項9または10に記載の交換結合膜。

【請求項12】 前記元素X'は、Ne, Ar, Kr, Xeのうち1種または2種以上の元素である請求項11記載の交換結合膜。

【請求項13】 前記元素X'の組成比はat%で、0.2~10の範囲内である請求項9ないし12のいずれかに記載の交換結合膜。

【請求項14】 前記元素X'の組成比はat%で、0.5~5の範囲内である請求項13記載の交換結合膜。

20 【請求項15】 元素XとMnとの組成比の割合X:Mnは、4:6~6:4の範囲内である請求項13または14に記載の交換結合膜。

【請求項16】 前記反強磁性層として用いられるX-Mn-X'合金は、スパッタ法により形成される請求項9ないし15のいずれかに記載の交換結合膜。

【請求項17】 前記反強磁性層が、X-Mn合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、X-Mn合金のXの組成比はat%で、47~57の範囲内である請求項1、7、8のいずれかに記載の交換結合膜。

【請求項18】 前記反強磁性層が、X-Mn-X'合金（ただし、Xは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素であり、X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、X-Mn-X'合金のX+X'の組成比はat%で、47~57の範囲内である請求項13ないし15のいずれかに記載の交換結合膜。

【請求項19】 X-Mn合金のXの組成比、あるいはX-Mn-X'合金のX+X'の組成比はat%で、50~56の範囲内である請求項17または18記載の交換結合膜。

50 【請求項20】 前記反強磁性層が、X-Mn合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうち

いずれか1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の下に形成されており、X-Mn合金のXの組成比はa t %で、44~57の範囲内である請求項1、7、8のいずれかに記載の交換結合膜。

【請求項21】 前記反強磁性層が、X-Mn-X'合金(ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の下に形成されており、X-Mn-X'合金のX+X'の組成比はa t %で、44~57の範囲内である請求項13ないし15のいずれかに記載の交換結合膜。

【請求項22】 X-Mn合金のXの組成比、あるいはX-Mn-X'合金のX+X'の組成比はa t %で、46~55の範囲内である請求項20または21記載の交換結合膜。

○【請求項23】 反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性導電層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層と、固定磁性層と非磁性導電層とフリー磁性層に検出電流を与える導電層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項1ないし請求項22のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

○【請求項24】 前記フリー磁性層の上側または下側に、トラック幅Twの間隔を空けて反強磁性層が積層され、前記反強磁性層とフリー磁性層とが、請求項1ないし請求項22のいずれかに記載された交換結合膜により形成されている請求項23記載の磁気抵抗効果素子。

○【請求項25】 フリー磁性層の上下に積層された非磁性導電層と、一方の前記非磁性導電層の上および他方の非磁性導電層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項1ないし請求項22のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

○【請求項26】 非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅Twの間隔を空けて反強磁性層が形成

され、前記反強磁性層と磁気抵抗層とが、請求項1ないし請求項22のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

○【請求項27】 請求項23ないし26のいずれかに記載された磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とする薄膜磁気ヘッド。

【発明の詳細な説明】

【0001】

10 【発明の属する技術分野】本発明は、反強磁性層と強磁性層とから成り、前記反強磁性層と強磁性層との界面にて発生する交換異方性磁界により、前記強磁性層の磁化方向が一定の方向に固定される交換結合膜に係り、特に前記反強磁性層が元素X(Pt, Pd等)とMnとを含有する反強磁性材料で形成された場合、より大きい交換異方性磁界を得られるようにした交換結合膜およびこの交換結合膜を用いた磁気抵抗効果素子(スピンバルブ型薄膜素子、AMR素子)に関する。

【0002】

20 【従来の技術】スピンバルブ型薄膜素子は、巨大磁気抵抗効果を利用したGMR(giant magnetoresistive)素子の1種であり、ハードディスクなどの記録媒体からの記録磁界を検出するものである。このスピンバルブ型薄膜素子は、GMR素子の中でも比較的構造が単純で、しかも弱い磁界で抵抗が変化するなど、いくつかの優れた点を有している。

【0003】前記スピンバルブ型薄膜素子は、最も単純な構造で、反強磁性層、固定磁性層、非磁性導電層およびフリー磁性層から成る。前記反強磁性層と固定磁性層とは接して形成され、前記反強磁性層と固定磁性層との界面にて発生する交換異方性磁界により、前記固定磁性層の磁化方向は一定方向に単磁区化され固定される。フリー磁性層の磁化は、その両側に形成されたバイアス層により、前記固定磁性層の磁化方向と交叉する方向に揃えられる。

【0004】前記反強磁性層にはFe-Mn(鉄-マンガ)合金膜、またはNi-Mn(ニッケル-マンガ)合金膜、固定磁性層及びフリー磁性層にはNi-Fe(ニッケル-鉄)合金膜、非磁性導電層3にはCu(銅)膜、またバイアス層にはCo-Pt(コバルト-白金)合金膜などが一般的に使用されている。

【0005】このスピンバルブ型薄膜素子では、ハードディスクなどの記録媒体からの漏れ磁界により、前記フリー磁性層の磁化方向が変動すると、固定磁性層の固定磁化方向との関係で電気抵抗が変化し、この電気抵抗値の変化に基づく電圧変化により、記録媒体からの洩れ磁界が検出される。

【0006】ところで、前述したように、反強磁性層には、Fe-Mn合金膜やNi-Mn合金膜が用いられるが、Fe-Mn合金膜は、耐食性が低く、また交換異方

性磁界が小さく、さらにブロッキング温度が150℃程度と低くなっている。ブロッキング温度が低いことで、ヘッドの製造工程中やヘッド動作中における素子温度の上昇により、交換異方性磁界が消失してしまうという問題が発生する。これに対し、Ni-Mn合金膜は、Fe-Mn合金膜に比べて、交換異方性磁界が比較的大きく、しかもブロッキング温度が約300℃と高い。従って反強磁性層には、Fe-Mn合金膜よりもNi-Mn合金膜を用いる方が好ましい。

【0007】また、B. Y. Wong, C. Mitsu-
mata, S. Prakash, D. E. Laughl-
in, and T. Kobayashi: Journa-
l of Applied Physics, vol.
79, No. 10, p. 7896-p. 7904 (199
6) には、Ni-Mn合金膜を反強磁性層として用いた
場合における前記反強磁性層と固定磁性層(NiFe合
合金膜)との界面構造について報告されている。

【0008】この論文には、「NiFeとNiMnの両
方の{111}面が膜面と平行となるように、NiFe
/NiMn界面での結晶整合状態を保って成長してい
る。界面での整合歪みは、膜面と平行な面を双晶面とす
る双晶が多数導入されることにより緩和されている。た
だし、残存している界面歪みにより、界面近くでのNi
Mnの規則化は低く抑制され、界面から離れた場所では
規則化度が高くなっている。」と記載されている。

【0009】なお、整合とは、界面における反強磁性層
と固定磁性層との原子が、1対1で対応する状態のこ
とをいい、逆に非整合とは、界面における反強磁性層と固
定磁性層との原子が1対1の位置関係にない状態のことを
いう。

【0010】NiMn合金で反強磁性層が形成される場
合、熱処理が施されることにより、NiMn合金と固定
磁性層との界面に、交換異方性磁界が発生するが、これ
は熱処理が施されることにより、NiMn合金が不規則
格子から規則格子に変態することによる。

【0011】熱処理が施される前では、NiMn合金の
結晶構造は、Ni, Mn原子の配列順序が不規則な面心
立方格子(以下、不規則格子という)であるが、熱処理
が施されると、結晶構造は、面心立方格子から面心正
方格子に変態し、しかも原子位置が規則化(以下規則格子
という)する。なお、結晶構造が完全に規則格子となっ
た場合におけるNi-Mn合金膜の格子定数a, cの比
c/aは、0.942である。

【0012】このように、完全に規則格子となったNi
Mn合金膜の格子定数比c/aは、比較的1に近い値で
あるため、不規則格子から規則格子に変態する時に生じ
る界面での格子歪みは、比較的小さくなっており、従っ
てNiMn合金膜と固定磁性層との界面構造が整合状態
にあっても、熱処理が施されることにより、NiMn合
金が不規則格子から規則格子に変態し、交換異方性磁界

が発生する。なお前述した論文に記載されているよう
に、界面における格子歪みは、双晶によりある程度緩和
されている。

【0013】

【発明が解決しようとする課題】前述したように、Ni
Mn合金は、比較的交換異方性磁界が大きく、またブロ
ッキング温度も約300℃と高くなっており、従来のFe
Mn合金に比べて優れた特性を有しているが、耐食性
に関しては、FeMn合金と同じ様に、充分であるとは
いえなかった。

【0014】そこで最近では、耐食性に優れ、しかもN
iMn合金よりも大きい交換異方性磁界を発生し、高い
ブロッキング温度を有する反強磁性材料として、白金族
元素を用いたX-Mn合金(X=Pt, Pd, Ir, R
h, Ru, Os)が注目を浴びている。白金族元素を
含有するX-Mn合金を反強磁性層として用いれば、従来
に比べて再生出力を向上させることができ、またヘッド
駆動動作時における素子温度の上昇により、交換異方性
磁界が消滅し再生特性が低下するといった不具合も生じ
にくくなる。

【0015】ところで、この白金族元素を含有するX-
Mn合金を反強磁性層として用いた場合、交換異方性磁
界を発生させるには、NiMn合金を反強磁性層として
用いた場合と同様に、成膜後熱処理を施す必要がある。
NiMn合金の場合、前述した文献によれば、固定磁性
層(NiFe合金)との界面構造は整合状態となってい
ると記載されているが、X-Mn合金(Xは白金族元
素)の場合も同じ様に、固定磁性層との界面構造を整合
状態としておくと、熱処理を施しても交換異方性磁界が
ほとんど発生しないことがわかった。

【0016】本発明は上記従来の課題を解決するための
ものであり、反強磁性層として、元素X(Xは白金族元
素)とMnとを含有する反強磁性材料を用いた場合、大
きい交換異方性磁界を発生することができるようにした
交換結合膜、およびこの交換結合膜を用いた磁気抵抗効
果素子に関する。

【0017】

【課題を解決するための手段】本発明は、反強磁性層と
強磁性層とが接して形成され、熱処理が施されること
により、前記反強磁性層と強磁性層との界面にて交換異
方性磁界が発生し、前記強磁性層の磁化方向が一定方向に
固定される交換結合膜において、前記反強磁性層は、少
なくとも元素X(ただしXは、Pt, Pd, Ir, R
h, Ru, Osのうちいずれか1種または2種以上の元
素である)とMnとを含有する反強磁性材料で形成さ
れ、前記反強磁性層と強磁性層との界面構造が、非整合
状態にあることを特徴とするものである。

【0018】また、熱処理後における前記反強磁性層の
少なくとも一部の結晶構造が、L1₂型の面心正方規則
格子となっていることが好ましい。さらに本発明では、

前記反強磁性層と強磁性層との界面にて、前記反強磁性層および強磁性層の結晶配向が異なっていることが好ましい。

【0019】本発明では、前記強磁性層の{111}面が、前記反強磁性層との界面に平行な方向に優先配向するのに対し、前記反強磁性層の{111}面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となっている。

【0020】あるいは、前記反強磁性層の{111}面が、前記強磁性層との界面に平行な方向に優先配向するのに対し、前記強磁性層の{111}面の配向度は、前記反強磁性層の配向度よりも小さいか、あるいは無配向となっている。

【0021】あるいは、前記反強磁性層と強磁性層との界面に平行な方向への、前記反強磁性層の{111}面の配向度、および前記強磁性層の{111}面の配向度は共に小さくなっているか、あるいは無配向となっており、前記{111}面以外の結晶面が、界面に平行な方向へ優先配向されて、反強磁性層と強磁性層の結晶配向が異なっている。

【0022】また本発明では、前記反強磁性層はX-Mn合金で形成され、元素Xは、Ptであることが好ましい。さらに、前記反強磁性層がPtMn合金で形成される場合、熱処理後における前記反強磁性層の格子定数a、cの比 c/a は、0.93~0.99の範囲内であることが好ましい。

【0023】または本発明では、前記反強磁性層は、X-Mn-X'合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成され、前記X-Mn-X'合金は、元素XとMnとで構成される空間格子の隙間に元素X'が侵入した侵入型固溶体であり、あるいは、元素XとMnとで構成される結晶格子の格子点の一部が、元素X'に置換された置換型固溶体である。特に、前記反強磁性層として用いられるX-Mn-X'合金の元素XはPtである、すなわち前記反強磁性層は、Pt-Mn-X'合金により形成されていることが好ましい。

【0024】なお本発明では、前記反強磁性層として用いられるX-Mn-X'合金の元素X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素であることが好ましく、より好ましくは、前記元素X'は、Ne, Ar, Kr, Xeのうち1種または2種以上の元素である。

【0025】また本発明では、前記反強磁性層が、X-Mn-X'合金で形成される場合、X'の組成比はat%で、0.2~10の範囲内であることが好ましく、よ

り好ましくは、0.5~5の範囲内である。

【0026】さらに本発明では、前記反強磁性層が、X-Mn-X'合金で形成される場合、元素XとMnとの組成比の割合X:Mnは、4:6~6:4の範囲内であることが好ましい。なお前記反強磁性層として用いられるX-Mn-X'合金は、スパッタ法により形成されることが好ましい。

【0027】本発明では、前記反強磁性層が、X-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の上に形成されており、X-Mn合金のXの組成比はat%で、47~57の範囲内であることが好ましい。

【0028】また本発明では、前記反強磁性層が、X-Mn-X'合金(ただし、Xは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素であり、X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の上に形成されており、X-Mn-X'合金のX+X'の組成比はat%で、47~57の範囲内であることが好ましい。

【0029】さらに本発明では、X-Mn合金のXの組成比、あるいはX-Mn-X'合金のX+X'の組成比はat%で、50~56の範囲内であることがより好ましい。

【0030】本発明では、前記反強磁性層が、X-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の下に形成されており、X-Mn合金のXの組成比はat%で、44~57の範囲内であることが好ましい。

【0031】また本発明では、前記反強磁性層が、X-Mn-X'合金(ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成され、前記反強磁性層が強磁性層の下に形成されており、X-Mn-X'合金のX+X'の組成比はat%で、44~57の範囲内であることが好ましい。

【0032】さらに本発明では、X-Mn合金のXの組成比、あるいはX-Mn-X'合金のX+X'の組成比はat%で、46~55の範囲内であることがより好ましい。

【0033】以上のようにして形成された交換結合膜

は、本発明では、様々な磁気抵抗効果素子に使用可能である。まず本発明におけるシングルスピンバルブ型薄膜素子は、反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性導電層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層と、固定磁性層と非磁性導電層とフリー磁性層に検出電流を与える導電層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、前述した交換結合膜により形成されていることを特徴とするものである。

【0034】また本発明では、上記シングルスピンバルブ型薄膜素子のフリー磁性層の上側または下側に、トラック幅 T_w の間隔を空けて反強磁性層が形成され、前記反強磁性層とフリー磁性層とが、前述した交換結合膜により形成されているものであってもよい。

【0035】また本発明におけるデュアルスピンバルブ型薄膜素子は、フリー磁性層の上下に積層された非磁性導電層と、一方の前記非磁性導電層の上および他方の非磁性導電層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、前述した交換結合膜により形成されていることを特徴とするものである。

【0036】さらに本発明におけるAMR素子は、非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅 T_w の間隔を空けて反強磁性層が形成され、前記反強磁性層と磁気抵抗層とが、前述した交換結合膜により形成されていることを特徴とするものである。また本発明における薄膜磁気ヘッドは、前述した磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とするものである。

【0037】本発明では、反強磁性層として、少なくとも元素X（X=Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種あるいは2種以上の元素）とMnを含む反強磁性材料を使用した場合、強磁性層との界面構造を非整合状態として、適性に交換異方性磁界を得られるようにするものである。

【0038】強磁性層との界面構造を非整合状態とする理由は、熱処理を施したとき、反強磁性層の結晶構造を、不規則格子から規則格子に適性に変態させ、より大きい交換異方性磁界を発生させるためである。以下に、前記非整合状態と交換異方性磁界との関係について詳述する。

【0039】まず、非整合状態とは、反強磁性層と強磁性層との界面において、前記反強磁性層側の原子と、強磁性層側の原子とが1対1に対応しておらず、原子の位置関係が異なることをいうが、このように界面構造を非整合状態とするには、熱処理前における反強磁性層の格子定数を適性に制御しておく必要がある。

【0040】本発明では、前記反強磁性層は、例えばX-Mn合金（ただし、XはPt, Pd, Ir, Rh, Ru, Osのうちいずれか1種あるいは2種以上の元素）で形成される。

【0041】本発明では、前記X-Mn合金のXの組成比を適性に選択して、熱処理前におけるX-Mn合金の格子定数の値と、強磁性層（例えばNiFe合金）の格子定数の値との差が大きくなるようにしている。

【0042】成膜段階（熱処理前）におけるX-Mn合金の結晶構造と強磁性層の結晶構造とは共に、X, Mn原子の配列順序が不規則な面心立方格子（以下、不規則格子という）となっているが、本発明では前述したように、X-Mn合金の格子定数と強磁性層の格子定数との差を大きくしているので、成膜段階（熱処理前）でのX-Mn合金と強磁性層との界面構造は非整合状態になりやすくなっている。

【0043】このように本発明では、反強磁性層としてX-Mn合金（XはPt, Pd等）を使用した場合、元素Xの組成比を適正に選択することにより、反強磁性層と、強磁性層との界面状態を非整合状態にしているが、さらに本発明では、希ガス元素（NeやAr等）などの元素X'をX-Mn合金に含有させることで、反強磁性層の格子定数を大きくでき、前記反強磁性層と強磁性層との界面構造を非整合状態にすることが可能になっている。

【0044】また本発明では、X-Mn合金、あるいはX-Mn-X'合金と強磁性層との結晶配向が異なるようにしておくことが好ましい。結晶配向度は下地層の存否や、組成比、スパッタ成膜時の電力ガス圧等の諸条件、あるいは膜の積層順などにより変えることが可能である。

【0045】このように、X-Mn合金、あるいはX-Mn-X'合金と強磁性層との結晶配向が異なるようにしておくのは、例えば強磁性層の{111}面が、膜面に平行に優先配向し、同じ様にX-Mn合金、あるいはX-Mn-X'合金の{111}面が、膜面に平行に優先配向していると、界面構造は非整合状態には成りにくくなるからである。

【0046】そこで本発明では、例えば強磁性層の{111}面が、X-Mn合金、あるいはX-Mn-X'合金との界面に平行な方向に優先配向している場合、X-Mn合金、あるいはX-Mn-X'合金の{111}面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となるように適性に制御することで、界面

構造を非整合状態に保つことが可能となる。

【0047】以上のように、界面構造が非整合状態となるように、X-Mn合金、あるいはX-Mn-X'合金と強磁性層とを積層した後、熱処理を施すことにより、X-Mn合金、あるいはX-Mn-X'合金と強磁性層との界面にて交換異方性磁界が発生するが、この交換異方性磁界の発生は、X-Mn合金、あるいはX-Mn-X'合金の結晶構造が、前記不規則相からX、Mn原子の配列順序が規則性をもって決められた面心正方格子に変態することによるものである。

【0048】なお、本発明では、前記面心正方格子は、単位格子の6面のうち、側面の4面の中心をX原子が占め、単位格子の隅、および上面および下面の中心にMn原子が占める、いわゆるL1₁型の面心正方格子（以下、規則格子という）であり、熱処理後におけるX-Mn合金、あるいはX-Mn-X'合金の少なくとも一部の結晶構造が、前記規則格子となっている必要がある。

【0049】以上のように、熱処理を施すことによりX-Mn合金、あるいはX-Mn-X'合金の結晶構造が、不規則格子から規則格子に変態し、交換結合磁界が発生するが、この変態の際に生じる格子歪みは、X-Mn合金、あるいはX-Mn-X'合金の方がNiMn合金に比べて大きくなっている。

【0050】本発明では、前述したように、X-Mn合金の組成比を適性化することにより、あるいはX-Mn合金に第3元素として元素X'を添加することにより、熱処理前におけるX-Mn合金、あるいはX-Mn-X'合金と強磁性層との界面構造を非整合状態にできる。

【0051】反強磁性層と強磁性層との界面構造を非整合状態にすると、熱処理を施すことにより、X-Mn合金、あるいはX-Mn-X'合金の結晶構造は不規則格子から規則格子に変態しやすくなり、従って前記界面にて大きな交換異方性磁界が発生する。なお、X-Mn合金（X=Pt、Pd等）、あるいはX-Mn-X'合金（X'=Ne、Ar等）は、FeMn合金やNiMn合金などに比べて耐食性に優れ、またFeMn合金等と比べて、ブロッキング温度も高く、さらに交換異方性磁界（Hex）が大きいなど反強磁性材料として優れた特性を有している。また、本発明ではX-Mn合金、あるいはX-Mn-X'合金を構成する元素XにPtを選択することが好ましい。

【0052】以上詳述した、X-Mn合金、あるいはX-Mn-X'合金で形成された反強磁性層と強磁性層とから成る交換結合膜は、磁気抵抗効果素子に適用することが可能である。

【0053】本発明では、例えば前記磁気抵抗効果素子としてシングルスピンバルブ型薄膜素子およびデュアルスピンバルブ型薄膜素子の反強磁性層と固定磁性層とを、前記交換結合膜により形成している。これにより、

前記固定磁性層の磁化を一定方向に強固に固定することが可能となり、従来に比べて優れた再生特性を得ることが可能となっている。

【0054】また、エキスチェンジバイアス方式により、例えばシングルスピンバルブ型薄膜素子のフリー磁性層、あるいはAMR素子の磁気抵抗効果素子層の磁化方向を一定の方向に揃える場合、エキスチェンジバイアス層とフリー磁性層、あるいはエキスチェンジバイアス層と磁気抵抗層とを、前記交換結合膜により形成してもよい。これにより、前記フリー磁性層および磁気抵抗層の磁化を一定方向に適性に揃えることが可能となり、優れた再生特性を得ることが可能である。

【0055】

【発明の実施の形態】図1は、本発明の第1実施形態のシングルスピンバルブ型薄膜素子の構造をABS面側から見た断面図である。なお、図1ではX方向に延びる素子の中央部分のみを破断して示している。このシングルスピンバルブ型薄膜素子は、ハードディスク装置に設けられた浮上式スライダのトレーリング側端部などに設けられて、ハードディスクなどの記録磁界を検出するものである。なお、ハードディスクなどの磁気記録媒体の移動方向はZ方向であり、磁気記録媒体からの洩れ磁界の方向はY方向である。

【0056】図1の最も下に形成されているのはTa（タンタル）などの非磁性材料で形成された下地層6である。この下地層6の上にフリー磁性層1、非磁性導電層2、固定磁性層3、および反強磁性層4が積層されている。そして、前記反強磁性層4の上にTa（タンタル）などの保護層7が形成されている。

【0057】また図1に示すように、下地層6から保護層7までの6層の両側には、ハードバイアス層5、5が形成され、前記ハードバイアス層5、5の上には導電層8、8が積層されている。

【0058】本発明では前記フリー磁性層1および固定磁性層3が、NiFe合金、CoFe合金、Co合金、Co、CoNiFe合金などにより形成されている。なお図1に示すようにフリー磁性層1は一層で形成されているが、これが多層構造で形成されてもよい。つまり、前記フリー磁性層1が、例えばNiFe合金とCoFe合金とが積層された構造となってもよいし、NiFe合金とCoとが積層された構造でもよい。

【0059】前記フリー磁性層1と固定磁性層3との間に介在する非磁性導電層2は、Cuで形成されている。さらに、ハードバイアス層5、5は、例えばCo-Pt（コバルト-白金）合金やCo-Cr-Pt（コバルト-クロム-白金）合金などで形成されており、導電層8、8は、Cu（銅）やW（タングステン）、Cr（クロム）などで形成されている。

【0060】本発明では、固定磁性層3の上に形成されている反強磁性層4は、少なくとも元素X（ただしX

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は、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)とMnとを含有する反強磁性材料によって形成されている。

【0061】本発明では、図1に示す固定磁性層3と反強磁性層4との界面構造は、非整合状態となっており、また界面における前記反強磁性層4の少なくとも一部の結晶構造は、L1₁型の面心正方格子(以下、規則格子という)となっている。

【0062】ここで、L1₁型の面心正方格子とは、単位格子の6面のうち、側面の4面の中心をX原子(X = Pt, Pd, Ir, Rh, Ru, Os)が占め、単位格子の隅、および上面および下面の中心にMn原子が占めるものをいう。

【0063】また本発明では、固定磁性層3と反強磁性層4との結晶配向が異なっていることが、固定磁性層3と反強磁性層4との界面構造が、非整合状態になりやすい点で好ましい。

○【0064】図1に示すシングルバルブ型薄膜素子では、Taの下地層6が敷いてあるので、前記下地層6の上に形成されるフリー磁性層1、非磁性導電層2、および固定磁性層3の{111}面は、膜面に対して平行な方向に優先配向している。

○【0065】これに対し、前記固定磁性層3の上に形成される反強磁性層4の{111}面は、前記固定磁性層3の{111}面の配向度と比べて小さいか、あるいは無配向となっている。つまり、図1に示す固定磁性層3と反強磁性層4との界面付近での結晶配向は異なったものとなっており、従って前記界面における構造が非整合状態になりやすくなっている。

【0066】本発明では熱処理前の段階から、固定磁性層3と反強磁性層4との界面構造を非整合状態としているが、これは熱処理を施すことにより、前記反強磁性層4の結晶構造を、不規則格子(面心立方格子)から前述した規則格子に変態させ、適性な交換異方性磁界を得られるようにするためである。言い換えれば、界面構造が整合状態にあると、熱処理を施しても、前記反強磁性層4の結晶構造が、不規則格子から規則格子に変態しにくく、従って交換異方性磁界が得られないという問題が生じる。

【0067】本発明では、前記反強磁性層4は、X-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成されている。特に本発明では、前記反強磁性層4がPtMn合金により形成されていることが好ましい。X-Mn合金、特にPtMn合金は、従来から反強磁性層として使用されているFeMn合金、NiMn合金などに比べて耐熱性に優れており、またブロッキング温度も高く、さらに交換異方性磁界(H_{ex})が大きいなど反強磁性材料として優れた特性を有している。

【0068】本発明では、前記反強磁性層4がPtMn

合金で形成されている場合、熱処理を施した後、つまり少なくとも一部の結晶構造が規則格子となった前記反強磁性層4の格子定数a, cの比c/aは、0.93~0.99の範囲内であることが好ましい。格子定数a, cの比c/aが0.93以下になると、前記反強磁性層4の結晶構造のほぼ全てが規則格子となるが、このような状態になると、前記固定磁性層3と反強磁性層4との密着性が低下し、膜剥がれなどが発生し好ましくない。格子定数a, cの比c/aが0.99以上になると、前記反強磁性層4の結晶構造のほぼ全てが不規則格子となってしまう、前記反強磁性層4と固定磁性層3との界面にて発生する交換異方性磁界が小さくなってしまい好ましくない。

【0069】ところで前記反強磁性層4が、X-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成される場合、熱処理前の段階において、固定磁性層3と反強磁性層4との界面構造を非整合状態とするために、本発明では、前記X-Mn合金の組成比を下記の数値内に設定している。

【0070】前記反強磁性層4が、X-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)で形成され、しかも図1に示すように前記反強磁性層4が固定磁性層3の上に形成される場合、X-Mn合金の元素Xの組成比はa t%で、47~57の範囲内であることが好ましい。より好ましくはX-Mn合金の元素Xの組成比はa t%で、50~56の範囲内である。

【0071】上述した組成比内で反強磁性層4を形成すると、熱処理前、つまり結晶構造が不規則格子となっている段階での前記反強磁性層4の格子定数と、固定磁性層3の格子定数との差を大きくすることができ、従って熱処理前にて、前記固定磁性層3と反強磁性層4との界面構造を非整合状態に保つことができる。

【0072】この状態で熱処理を施すと、前記反強磁性層4の結晶構造の変化により、交換異方性磁界が発生し、前述したようにX-Mn合金の元素Xの組成比の組成比がa t%で、47~57の範囲内であると、400(Oe:エルステッド)以上の交換異方性磁界を得ることが可能である。またX-Mn合金の元素Xの組成比はa t%で、50~56の範囲内であると、600(Oe)以上の交換異方性磁界を得ることが可能である。

【0073】このように本発明では、反強磁性層4としてX-Mn合金を使用した場合、元素Xの組成比を上述した範囲内で形成することにより、熱処理前における前記反強磁性層4と固定磁性層3との界面構造を非整合状態に保つことが可能である。また本発明では、X-Mn合金に、第3元素として元素X'を添加することにより、反強磁性層4の格子定数を大きくでき、熱処理前における反強磁性層4と固定磁性層3との界面構造を非整

合状態にすることが可能である。

【0074】X-Mn合金に元素X'を加えたX-Mn-X'合金は、元素XとMnとで構成される空間格子の隙間に元素X'が侵入した侵入型固溶体であり、あるいは、元素XとMnとで構成される結晶格子の格子点の一部が、元素X'に置換された置換型固溶体である。ここで固溶体とは、広い組成範囲にわたって、均一に成分が混ざり合った固体のことを指している。なお本発明では元素XはPtであることが好ましい。

【0075】ところで本発明では前記X-Mn-X'合金をスパッタ法により成膜している。スパッタによって、前記X-Mn-X'合金は非平衡状態で成膜され、成膜されたX-Mn-X'合金は、膜中の元素X'が、元素XとMnとで構成される空間格子の隙間に侵入し、あるいは、元素XとMnとで構成される結晶格子の格子点の一部が、元素X'に置換される。このように、前記元素X'が、X-Mn合金の格子に侵入型であるいは置換型で固溶することにより、格子は押し広げられ、反強磁性層4の格子定数は、元素X'を添加しない場合に比べ大きくなる。

【0076】また本発明では、元素X'として様々な元素を使用することが可能であるが、反応性の高いハロゲンやO(酸素)等を使用すると、これらがMnとのみ選択的に化学結合してしまい、面心立方晶の結晶構造を保てなくなると考えられ好ましくない。本発明における具体的な元素X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素(Sc, Yとランタノイド(La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu))のうち1種または2種以上の元素である。

【0077】上記に示した様々な元素X'のいずれを使用しても、スパッタによって、反強磁性層4の格子定数を大きくできるが、特に置換型で固溶する元素X'を使用する場合は、前記元素X'の組成比が大きくなりすぎると、反強磁性としての特性が低下し、固定磁性層3との界面で発生する交換結合磁界が小さくなってしまふ。

【0078】特に本発明では、侵入型で固溶し、不活性ガスの希ガス元素(Ne, Ar, Kr, Xeのうち1種または2種以上)を元素X'として使用することが好ましいとしている。希ガス元素は不活性ガスなので、希ガス元素が、膜中に含有されても、反強磁性特性に大きく影響を与えることがなく、さらに、Arなどは、スパッタガスとして従来からスパッタ装置内に導入されるガスであり、ガス圧やスパッタ粒子のエネルギーを適正に調節するので、容易に、膜中にArを侵入させることができる。

【0079】なお、元素X'にガス系の元素を使用した

場合には、膜中に多量の元素X'を含有することは困難であるが、希ガスの場合においては、膜中に微量侵入させるだけで、熱処理によって発生する交換結合磁界を、飛躍的に大きくできることが実験により確認されている。

【0080】なお本発明では、元素X'の組成比の範囲を設定しており、好ましい前記元素X'の組成範囲は、at%で0.2から10であり、より好ましくは、at%で、0.5から5である。またこのとき、元素XとMnとの組成比の割合X:Mnは、4:6~6:4の範囲内であることが好ましい。元素X'の組成比と、元素XとMnとの組成比の割合X:Mnを、上記範囲内で調整すれば、成膜段階(熱処理前)における反強磁性層4の格子定数を大きくでき、しかも熱処理を施すことにより反強磁性層4と固定磁性層3との界面で発生する交換結合磁界を、元素X'を含有しない場合に比べ、大きくすることが可能である。

【0081】さらに本発明では、X-Mn-X'合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素であり、X'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成された反強磁性層4が、図1に示すように、固定磁性層3の上に形成される場合、前記X-Mn-X'合金のX+X'の組成比はat%で、47~57の範囲内であることが好ましく、より好ましくは、X-Mn-X'合金のX+X'の組成比はat%で、50~56の範囲内である。

【0082】熱処理を施すことによって反強磁性層4と固定磁性層3との界面で発生する交換結合磁界により、前記固定磁性層3の磁化は、図1に示すY方向に単磁区化され固定される。なお、反強磁性層4として使用されるX-Mn-X'合金の元素X'が例えばガス系の元素である場合には、熱処理を施すことにより、前記元素X'が膜中から抜け出て、成膜された段階での元素X'の組成比よりも、熱処理後の元素X'の組成比は小さくなり、あるいは完全に前記X'が膜中から抜け出してしまつて、組成がX-Mnになってしまうことがあるが、成膜段階(熱処理前)における固定磁性層3と反強磁性層4との界面構造が非整合状態となっていれば、熱処理を施すことにより、前記反強磁性層4の結晶構造は、不規則格子(面心立方格子)から規則格子に適性に変換し、大きい交換異方性磁界を得ることが可能である。またフリー磁性層1は、その両側に形成されているハードバイアス層5、5により、図示X方向に揃えられる。

【0083】図1に示すシングルスピンバルブ型薄膜素子では、導電層8からフリー磁性層1、非磁性導電層2

および固定磁性層3に定常電流（センス電流）が与えられ、しかも記録媒体からY方向へ磁界が与えられると、フリー磁性層1の磁化方向がX方向からY方向へ向けて変化する。このとき、伝導電子が、非磁性導電層2と固定磁性層3との界面、または非磁性導電層2とフリー磁性層1との界面で散乱を起し、電気抵抗が変化する。よって電圧が変化し、検出出力を得ることができる。

【0084】図2は、本発明の第2実施形態のシングルスピバルブ型薄膜素子の構造を示す断面図である。図2に示すように、下から下地層6、反強磁性層4、固定磁性層3、非磁性導電層2、およびフリー磁性層1が連続して積層されている。なお、図2に示す反強磁性層4は、図1に示す反強磁性層4と同じ様に、X-Mn合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）、好ましくはPtMn合金、またはX-Mn-X'合金（ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である）で形成されている。なお、固定磁性層3、非磁性導電層2、およびフリー磁性層1は、図1で説明した材質で形成されている。

【0085】この実施例においても、固定磁性層3と反強磁性層4との界面構造は、非整合状態となっており、また界面における前記反強磁性層4の少なくとも一部の結晶構造は、L1₁型の面心正方格子（以下、規則格子という）となっている。

【0086】またTaの下地層6の上に形成された前記反強磁性層4の{111}面は、界面に平行な方向に優先配向するが、図2に示すように、前記反強磁性層4の上に固定磁性層3が形成されると、前記固定磁性層3の{111}面の界面方向に対する配向度は、前記反強磁性層4の配向度よりも小さいか、あるいは無配向になり易い傾向がある。このように、図2では界面における前記反強磁性層4と固定磁性層3との結晶配向は異なっており、従ってより界面構造を非整合状態とすることが可能となっている。

【0087】ところで、反強磁性層4がX-Mn合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）で形成され、図2に示すように、反強磁性層4が固定磁性層3の下に形成される場合、反強磁性層4を構成するX-Mn合金の元素Xの組成比はat%で、44~57の範囲内であることが好ましい。この範囲内であれば、400（Oe）以上の交換異方性磁界を得ることが可能である。より好ましくはX-Mn合金の元素Xの組成比はat%で、46~55の範囲内である。この範囲内であれば、600（Oe）以上の交換異方性磁界を得ることが

可能である。

【0088】このように上述した組成範囲内であると交換異方性磁界を大きくすることができるのは、熱処理前における反強磁性層4の格子定数（不規則格子）と、固定磁性層3の格子定数との差を大きくすることができ、熱処理前での界面構造を非整合状態とすることができるからである。従って熱処理を施すことにより、界面における前記反強磁性層4の少なくとも一部の結晶構造を、不規則格子から交換異方性磁界を発揮するために必要な規則格子に変態させることが可能となる。

【0089】また前記反強磁性層4が、X-Mn-X'合金（ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である）で形成される場合、前記X-Mn-X'合金は、スパッタ法によって形成され、元素XとMnとで構成される空間格子の隙間に元素X'が侵入した侵入型固溶体となり、あるいは、元素XとMnとで構成される結晶格子の格子点の一部が、元素X'に置換された置換型固溶体となっている。

【0090】元素X'を膜中に含有する反強磁性層4の格子定数は、前記元素X'を含有しない反強磁性層4の格子定数に比べて大きくなり、成膜段階（熱処理前）における反強磁性層4と固定磁性層3との界面構造を非整合状態に保つことができる。

【0091】なお本発明では、膜中に占める元素X'の組成比を、at%で、0.2~10の範囲内とし、より好ましい組成範囲をat%で、0.5~5の範囲内としている。また元素X'を前記組成範囲内で形成し、さらに、元素XとMnとの組成比の割合X:Mnを、4:6~6:4の範囲内とすれば、より大きい交換結合磁界を得ることが可能である。

【0092】また本発明では、図2に示すように、X-Mn-X'合金で形成された反強磁性層4が固定磁性層3の下側に形成される場合、X-Mn-X'合金のX+X'の組成比は、at%で、44~57の範囲内であることが好ましい。より好ましくはX-Mn-X'合金のX+X'の組成比はat%で、46~55の範囲内である。

【0093】なお、図2に示す固定磁性層3の磁化は、反強磁性層4との界面にて発生する交換異方性磁界により、図示Y方向に単磁区化され固定されている。

【0094】図2に示すように、フリー磁性層1の上には、トラック幅Twの間隔を空けてエキスチェンジバイアス層9（反強磁性層）が形成されている。なおこのエキスチェンジバイアス層9は、X-Mn合金（ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である）、好ましくはPt

Mn合金、またはX-Mn-X'合金(ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成されている。

【0095】X-Mn合金の元素Xの組成比はa t%で、47~57の範囲内となっている。より好ましくはX-Mn合金の元素Xの組成比はa t%で、50~56の範囲内である。なおこの組成範囲は、図1で説明した反強磁性層4の組成範囲と同じである。またX-Mn-X'合金の場合、元素X'の組成比はa t%で、0.2~1.0の範囲内であり、より好ましい組成範囲はa t%で、0.5~5の範囲内である。また元素XとMnとの組成比の割合X:Mnは、4:6~6:4の範囲内であることが好ましい。さらに、X-Mn-X'合金のX+X'の組成比はa t%で、47~57の範囲内となっていることが好ましく、より好ましくはX-Mn-X'合金のX+X'の組成比はa t%で、50~56の範囲内である。

【0096】上述した組成範囲内であると、フリー磁性層1とエキスチェンジバイアス層9との界面構造は非整合状態となり、少なくとも界面にて400(Oe)以上の交換異方性磁界を得ることができるが、図2に示すように、前記エキスチェンジバイアス層9、9は、トラック幅Tw部分には形成されていないので、フリー磁性層1の両端部分が、強く交換異方性磁界の影響を受け図示X方向に単磁区化され、フリー磁性層1のトラック幅Tw領域の磁化は、外部磁界に対して反応する程度に図示X方向に適性に揃えられている。

【0097】このようにして形成されたシングルスピバルブ型薄膜素子では、図示Y方向の外部磁界により、フリー磁性層1のトラック幅Tw領域の磁化が図示X方向から図示Y方向に変化する。このフリー磁性層1内での磁化の方向の変動と、固定磁性層3の固定磁化方向(図示Y方向)との関係で電気抵抗が変化し、この電気抵抗値の変化に基づく電圧変化により、記録媒体からの洩れ磁界が検出される。

【0098】図3は、本発明の第3実施形態のデュアルスピバルブ型薄膜素子の構造を示す断面図である。図に示す示すように、下から下地層6、反強磁性層4、固定磁性層3、非磁性導電層2、およびフリー磁性層1が連続して積層されている。さらに前記フリー磁性層1の上には、非磁性導電層2、固定磁性層3、反強磁性層4、および保護層7が連続して積層されている。また、下地層6から保護層7までの多層膜の両側にはハードバイアス層5、5、導電層8、8が積層されている。なお、各層は図1および図2で説明した材質と同じ材質で形成されている。

【0099】図3に示すように、フリー磁性層1よりも下側に形成されている反強磁性層4は、固定磁性層3の下に形成されているので、図2に示す反強磁性層4と同じ様に、前記反強磁性層4を構成するX-Mn合金の元素Xの組成比はa t%で、44~57の範囲内であることが好ましく、より好ましくはX-Mn合金の元素Xの組成比はa t%で、46~55の範囲内である。

【0100】また、フリー磁性層1よりも上側に形成されている反強磁性層4は、固定磁性層3の上に形成されているので、図1に示す反強磁性層4と同じ様に、前記反強磁性層4を構成するX-Mn合金の元素Xの組成比はa t%で、47~57の範囲内であることが好ましく、より好ましくはX-Mn合金の元素Xの組成比はa t%で、50~56の範囲内である。

【0101】この組成範囲内であれば、熱処理前における固定磁性層3の格子定数と反強磁性層4の格子定数との差を大きくすることができるので、熱処理前における界面構造を非整合状態にすることができ、従って熱処理を施すことにより、界面での前記反強磁性層4の一部の結晶構造を不規則格子から交換異方性磁界を発揮するのに必要な規則格子に変態させることが可能である。なお前記反強磁性層4がPtMn合金で形成される場合、熱処理後における前記反強磁性層4の格子定数a、cの比c/aは、0.93~0.99の範囲内であることが好ましい。また、反強磁性層4と固定磁性層3との結晶配向も異なっているため、より界面構造を非整合状態にすることが可能となっている。

【0102】上述した組成範囲内であれば、少なくとも400(Oe)以上の交換異方性磁界を得ることが可能であるが、反強磁性層4を固定磁性層3の下に形成する方が、固定磁性層3の上に形成するよりも、X-Mn合金の元素Xの組成比の範囲を若干広げることが可能である。

【0103】また反強磁性層4がX-Mn-X'合金で形成される場合は、元素X'の組成比は、a t%で、0.2~1.0の範囲内であり、より好ましい組成範囲はa t%で、0.5~5の範囲内である。また元素XとMnとの組成比の割合X:Mnは、4:6~6:4の範囲内であることが好ましい。

【0104】さらにフリー磁性層1よりも下側に形成されている反強磁性層4の場合、前記反強磁性層4を構成するX-Mn-X'合金のX+X'の組成比はa t%で、44~57の範囲内であることが好ましく、より好ましくはX-Mn-X'合金のX+X'の組成比はa t%で、46~55の範囲内である。

【0105】また、フリー磁性層1よりも上側に形成されている反強磁性層4の場合、前記反強磁性層4を構成するX-Mn-X'合金のX+X'の組成比はa t%で、47~57の範囲内であることが好ましく、より好ましくはX-Mn-X'合金のX+X'の組成比はa t

%で、50～56の範囲内である。

【0106】上記組成範囲内であれば、熱処理前における固定磁性層3の格子定数と反強磁性層4の格子定数との差を大きくすることができ、熱処理前における界面構造を非整合状態にすることができ、従って熱処理を施すことにより、界面での前記反強磁性層4の一部の結晶構造を不規則格子から交換異方性磁界を発揮するのに必要な規則格子に変態させることが可能である。

【0107】なおこのデュアルスピンバルブ型薄膜素子も図1に示すシングルスピンバルブ型薄膜素子と同じように、固定磁性層3は、交換異方性磁界により、図示Y方向に単磁区化され固定されており、フリー磁性層1の磁化は、ハードバイアス層5、5の影響を受けて図示X方向に揃えられている。

【0108】導電層8からフリー磁性層1、非磁性導電層2および固定磁性層3に定常電流が与えられ、しかも記録媒体からY方向へ磁界が与えられると、フリー磁性層1の磁化は図示X方向からY方向に変動し、このとき非磁性導電層2とフリー磁性層1との界面、および非磁性導電層2と固定磁性層3との界面でスピンの依存した伝導電子の散乱が起こることにより、電気抵抗が変化し、記録媒体からの漏れ磁界が検出される。

【0109】なお、図1および図2に示すシングルスピンバルブ型薄膜素子では、スピンの依存した電子の散乱を起こす場所が、非磁性導電層2とフリー磁性層1との界面、および非磁性導電層2と固定磁性層3との界面の2箇所であるのに対し、図3に示すデュアルスピンバルブ型薄膜素子では、伝導電子の散乱が起こる場所が、非磁性導電層2とフリー磁性層1との2箇所の界面と、非磁性導電層2と固定磁性層3との2箇所の界面の計4箇所であるため、デュアルスピンバルブ型薄膜素子の方がシングルスピンバルブ型薄膜素子に比べて大きい抵抗変化率を得ることが可能である。

【0110】図4は、本発明の第4実施形態のAMR型薄膜素子の構造を示す断面図である。図に示すように、下から軟磁性層(SAL層)10、非磁性層(SHUNT層)11、および磁気抵抗層(MR層)12が連続して積層されている。例えば前記軟磁性層10は、Fe-Ni-Nb合金、非磁性層11は、Ta膜、磁気抵抗層12は、NiFe合金により形成されている。

【0111】前記磁気抵抗層12の上には、トラック幅Twを開けたX方向両側の部分にエキスチェンジバイアス層(反強磁性層)9、9が形成され、さらに、前記エキスチェンジバイアス層9、9の上には、Cr膜などで形成された導電層13、13が形成されている。

【0112】図4に示すエキスチェンジバイアス層9、9は、図2に示すエキスチェンジバイアス層9、9と同様に、X-Mn合金、好ましくはPtMn合金で形成されており、X-Mn合金の元素Xの組成比はat%で、47～57の範囲内となっている。より好ましくはX-

Mn合金の元素Xの組成比はat%で、50～56の範囲内である。

【0113】また前記エキスチェンジバイアス層9、9は、X-Mn-X'合金(ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である)で形成されており、元素X'の組成比は、at%で、0.2～1.0の範囲内であり、より好ましい組成範囲はat%で、0.5～5の範囲内である。また元素XとMnとの組成比の割合X:Mnは、4:6～6:4の範囲内であることが好ましい。また図4に示すエキスチェンジバイアス層9、9は、図2に示すエキスチェンジバイアス層9、9と同様に、X-Mn-X'合金のX+X'の組成比はat%で、47～57の範囲内となっている。より好ましくはX-Mn-X'合金のX+X'の組成比はat%で、50～56の範囲内である。

【0114】以上X-Mn合金あるいはX-Mn-X'合金の組成比を上述した範囲内で形成すれば、前記エキスチェンジバイアス層9、9と磁気抵抗層12との界面構造は非整合状態となり、熱処理を施すことにより、NiFe合金の磁気抵抗層12の膜厚が200～300オングストロームの場合は、前記界面にて約40～110(Oe)の交換異方性磁界が得られ、とりわけ、NiFe合金の磁気抵抗層の膜厚が、約200オングストロームの場合には、約60～110(Oe)の交換異方性磁界が得られ、図4に示す磁気抵抗層12のB領域が、図示X方向に単磁区化される。そしてこれに誘発されて前記磁気抵抗層12のA領域の磁化が図示X方向に揃えられる。また、検出電流が磁気抵抗層12を流れる際に発生する電流磁界が、軟磁性層10にY方向に印加され、軟磁性層10がもたらす静磁結合エネルギーにより、磁気抵抗層12のA領域に横バイアス磁界がY方向に与えられる。X方向に単磁区化された磁気抵抗層12のA領域にこの横バイアス層が与えられることにより、磁気抵抗層12のA領域の磁界変化に対する抵抗変化(磁気抵抗効果特性:H-R効果特性)が直線性を有する状態に設定される。記録媒体の移動方向はZ方向であり、図示Y方向に漏れ磁界が与えられると、磁気抵抗層12のA領域の抵抗値が変化し、これが電圧変化として検出される。

【0115】以上詳述したように、本発明では、反強磁性層4(あるいはエキスチェンジバイアス層9)をX-Mn合金(ただしXは、Pt, Pd, Ir, Rh, Ru, Osのうちいずれか1種または2種以上の元素である)、好ましくはPtMn合金で形成する際に、前記反強磁性層4の組成比を適性に調節することにより、前記反強磁性層4と、この反強磁性層4と接して形成される

固定磁性層3（あるいはフリー磁性層1または磁気抵抗層12）との界面構造を非整合状態とすることができ、従ってより大きな交換異方性磁界を得られ、従来に比べて再生特性を高めることが可能である。あるいは、前記反強磁性層4（あるいはエキスチェンジバイアス層9）を元素XとMn以外に、第3元素として元素X'（ただしX'は、Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb、及び希土類元素のうち1種または2種以上の元素である）を添加することにより、前記元素X'を添加しない場合に比べ、反強磁性層4の格子定数を大きくすることができるので、前記反強磁性層4と、この反強磁性層4と接して形成される固定磁性層3（あるいはフリー磁性層1または磁気抵抗層12）との界面構造を非整合状態とすることができ、従ってより大きな交換異方性磁界を得ることができ、従来に比べて再生特性を高めることが可能である。また反強磁性層4と固定磁性層3との結晶配向を異なるようにしておくことが、より界面構造を非整合状態にしやすくできる点で好ましい。

【0116】また界面構造を非整合状態としておくことで交換異方性磁界を得ることができるのは、熱処理を施すことにより、前記反強磁性層4の結晶構造を不規則格子から規則格子に変態させることができるからであるが、すべての結晶構造が規則格子に変態すると密着性などに問題が生じるため、一部の結晶構造のみが規則格子に変態していることが好ましい。例えば前記反強磁性層4がPtMn合金で形成される場合、熱処理後における前記反強磁性層4の格子定数a, cの比 c/a は、0.93~0.99の範囲内であることが好ましい（ちなみにすべての結晶構造が規則格子に変体した場合、前記格子定数a, cの比 c/a は0.918である）。

【0117】なお、本発明では、磁気抵抗効果素子層の構造を図1~図4に示す構造に限定するものではない。例えば図1に示すシングルスピナルプ型薄膜素子の場合、ハードバイアス層5, 5を形成しないで、フリー磁性層1の下側にトラック幅Twの間隔を空けてエキスチェンジバイアス層を形成してもよいし、図2に示すシングルスピナルプ型薄膜素子の場合、エキスチェンジバイアス層9, 9を形成しないで、下地層6から保護層7までの6層の両側、あるいは少なくともフリー磁性層1の両側にハードバイアス層を形成してもよい。

【0118】図5は、図1から図4に示す磁気抵抗効果素子層が形成された読み取りヘッドの構造を記録媒体との対向面側から見た断面図である。符号20は、例えばNiFe合金などで形成された下部シールド層であり、この下部シールド層20の上に下部ギャップ層21が形成されている。また下部ギャップ層21の上には、図1から図4に示す磁気抵抗効果素子層22が形成されてお

り、さらに前記磁気抵抗効果素子層22の上には、上部ギャップ層23が形成され、前記上部ギャップ層23の上には、NiFe合金などで形成された上部シールド層24が形成されている。

【0119】前記下部ギャップ層21及び上部ギャップ層23は、例えばSiO₂やAl₂O₃（アルミナ）などの絶縁材料によって形成されている。図5に示すように、下部ギャップ層21から上部ギャップ層23までの長さがギャップ長G1であり、このギャップ長G1が小さいほど高記録密度化に対応できるものとなっている。

【0120】

【実施例】本発明では、まず下記に示す膜構成から成る多層膜を成膜し、反強磁性層を構成する一元素のPt量と、前記反強磁性層の格子定数との関係について調べた。膜構成としては、下からSi基板/アルミナ/下地層：Ta（100）/固定磁性層：NiFe（300）/反強磁性層：PtMn（300）/Ta（100）の順で積層した。なお上記括弧中の数値は膜厚を表わしており、単位はオングストロームである。実験は熱処理を施さない段階で、X線回折の $\theta/2\theta$ 法により、Pt量と反強磁性層の格子定数との関係を、回折パターンのピーク位置から求めた。

【0121】図6に示すように、Pt量が増加するにつれて、反強磁性層（PtMn）の格子定数が大きくなっていることがわかる。また固定磁性層を構成するNiFe合金、CoFe合金、またはCoの格子定数は、図に示すように、約3.5~3.6の範囲である。

【0122】次に、反強磁性層を固定磁性層の下、あるいは上に形成した2つの多層膜を、DCマグネトロンスパッタ法により成膜し、熱処理を施した後におけるPt量（反強磁性層を構成する一元素）と交換異方性磁界との関係について調べた。その実験結果を図7に示す。

【0123】反強磁性層が、固定磁性層の下に形成されている膜構成としては、下からSi基板/アルミナ/下地層：Ta（50）/反強磁性層：PtMn（300）/固定磁性層：Co₉₀Fe₁₀（30）/保護層：Ta（100）の順で積層し、前記反強磁性層が、固定磁性層の上に形成されている膜構成としては下から、Si基板/アルミナ/Ta（50）/固定磁性層：Co₉₀Fe₁₀（30）/反強磁性層（300）/保護層：Ta（100）の順で積層した。なお、上記括弧中の数値は膜厚を表わしており、単位はオングストロームである。

【0124】また熱処理工程における条件としては、まず昇温に3時間をかけ、次に240度の温度状態を3時間保持し、さらに、降温に3時間をかけた。なお、熱処理真空度を 5×10^{-4} Torr以下とした。

【0125】図7に示すように、反強磁性層（PtMn合金）が、固定磁性層の下側にある場合、および上側にある場合共に、Pt量が約50at%まで大きくなるにしたがって、交換異方性磁界は高くなっていき、Pt量

が約50at%以上になると、交換異方性磁界は徐々に小さくなっているのがわかる。

【0126】400(Oe)以上の交換異方性磁界を得るには、反強磁性層(PtMn)を固定磁性層の下側に形成した場合、Pt量を44~57at%の範囲内で、反強磁性層(PtMn)を固定磁性層の上側に形成した場合、Pt量を47~57at%の範囲内で適性に調節すればよいことがわかる。

【0127】また600(Oe)以上の交換異方性磁界を得るには、反強磁性層(PtMn)を固定磁性層の下 10 側に形成した場合、Pt量を46~55at%の範囲内

で、反強磁性層(PtMn)を固定磁性層の上側に形成した場合、Pt量を50~56at%の範囲内で適性に調節すればよいことがわかる。

【0128】以上の実験結果から、反強磁性層(PtMn)の組成比を適性に調節した実施例として4種類の多層膜を成膜し、比較例として1種類の多層膜を成膜し、各膜の配向性や、交換異方性磁界等について調べた。その実験結果を表1に示す。

【0129】

【表1】

表1

	膜構成	PtMn組成 (at%)	PtMn/Co-Fe 界面での 格子整合	PtMnの (111)配向	強磁性層/Cu/ 強磁性層部分の (111)配向	240℃熱処理 後のPtMnの 規則化度	交換結合磁界 Hex(Oe)	抵抗変化する (%)
①	基板/アルミナ/Ta(30Å)/ PtMn(300Å)/Co-Fe(30Å)/ Cu(22Å)/Co-Fe(10Å)/ Ni-Fe(70Å)/Ta(50Å)	Pt ₈₀ Mn ₂₀	なし	中	弱	○	770	6.7
②	基板/アルミナ/PtMn(300Å)/ Co(30Å)/Cu(24Å)/Ni-Fe(80Å)/ Ta(50Å)	Pt ₈₀ Mn ₂₀	なし	弱	弱	○	790	4.5
③	基板/アルミナ/Ta(50Å)/ Ni-Fe(70Å)/Co-Fe(10Å)/ Cu(28Å)/Co-Fe(30Å)/ PtMn(300Å)/Ta(50Å)	Pt ₈₀ Mn ₂₀	なし	弱	強	○	620	5.7
④	基板/アルミナ/Ta(30Å)/ PtMn(200Å)/Co-Fe(30Å)/ Cu(22Å)/Co-Fe(10Å)/ Ni-Fe(60Å)/Co-Fe(10Å)/ Cu(22Å)/Co-Fe(30Å)/ PtMn(200Å)/Ta(50Å)	Pt ₈₀ Mn ₂₀	なし	中	弱	○	610	8.3
⑤	③と同一	Pt ₈₀ Mn ₂₀	有り	強	強	×	40	0.2
実施例								
比較例								

実施例①～③までの多層膜は、シングルスピンバルブ型薄膜素子であり、実施例④の多層膜はデュアルスピンバルブ型薄膜素子である。また比較例⑤の多層膜は、実施例③の多層膜と同じ膜構成で、反強磁性層(PtMn)の組成比のみが異なっている。

【0130】また実施例①の多層膜には、Cu(非磁性導電層)の上に、Co-FeとNi-Feが積層されているが、この2層でフリー磁性層が構成されている。同じ様に実施例③の多層膜には、Cu(非磁性導電層)の下に、Ni-FeとCo-Feが積層されているが、こ

Taの上に形成されたNiFe、CoFe（フリー磁性層）、Cu（非磁性導電層）およびCoFe（固定磁性層）は、下地層としてのTaの影響を強く受けて、 $\{111\}$ 面の配向度は強くなり、図6を参照してわかるように熱処理前におけるCoFe（固定磁性層）の格子定

数とPtMn（反強磁性層）の格子定数との差が小さいために、PtMnの $\{111\}$ 面は、CoFeの $\{111\}$ 面の配向度の影響を強く受けて、膜面方向に優先配向してしまう。

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